The WELDING JOURNAL

JULY 1954

IN THIS ISSUE

Structural Welding of Railroad Cars ... 433

Portland High-School Welding Exposition ... 443

Automatic Position Welding of Tanks ... 451

Effect of Post-Heating ... 460

Corrosion Testing Tool for Weld Metal ... 467

Effect of Carbon Type on Electrode Coating ... 471

Effect of Thermal Conductivity ... 477

Corrosion in Gas Welds of Steel ... 484

Welding Wear-Resistant Surfaces ... 487

AWS Welding Standards ... 493

Program AWS Fall Meeting ... 495

Index to Advertisers ... 528

OFFICIAL PUBLICATION OF THE AMERICAN WELDING SOCIETY

RJ-38 TWECOTONG

"HOT-ROD" HOLDER

A BRUTE for BIG ROD and HIGH-AMPERAGE

ILLUSTRATION ACTUAL SIZE

designed for shops requiring HEAVY DUTY SERVICE with 1/4 — 5/16 and 3/8" rods . . .

This holder provides cool operation with a large diameter handle designed for maximum ventilation. Longer jaw life is assured by a special copper (welded-in) lower jaw insert. Cable connects to the holder with a detachable solder (RJ-38-DS) or a detachable mechanical (RJ-38-DM) fitting. Like all Twecotong holders, the RJ-38 is ruggedly built with high copper alloy castings for maximum electrical efficiency.

JOB-SELECT TWECOTONG TO FIT YOUR WELDING NEEDS — There is a Twecotong model for every type of duty from lightest work to heavy "hot-rod" service. Each one is "Super-Mel" insulated to withstand heavy impact, intense arc heat and yet retain its insulating qualities. Specify Twecotong for every job in your shop to get long life with maximum insulation and safety.

SEE YOUR LOCAL WELDING SUPPLY DISTRIBUTOR

Ask for Twecolog #8. Data and prices on the complete Tweco line of welding connections.

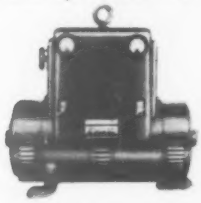
Tweco PRODUCTS COMPANY

MANUFACTURERS OF ELECTRODE HOLDERS • GROUND CLAMPS • CABLE CONNECTIONS FOR ELECTRIC WELDING

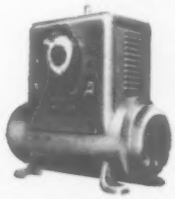
Try! Compare

. . . the new HOBART Arc Welders

. . . and you'll see why you get more actual benefits in dollar savings and INCREASED PROFITS! HOBART'S outstanding design and special features bring higher performance, faster welding and lower cost operation in a compact and easy to move unit.



For Automatic Welding



Bantam Champ

AC Transformer Welders

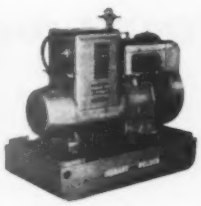
For Faster Production

Hobart welders will do your production work better and faster. They're available in 200, 300, 400 and 600 ampere sizes to do any job—light or heavy. An on the job comparison will prove their value . . . job after job you'll see Hobart outperform other welders, saving time and cutting production costs.

300 amp. Electric Portable

300 amp. Gas Engine Drive

250 amp. "Pipeliner"



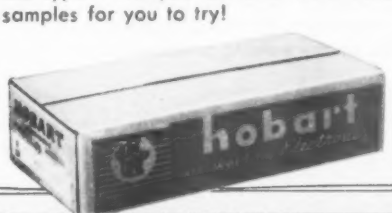
200 amp. Gas Engine Drive

For Repair and Maintenance

For repair and maintenance work Hobart offers a wide range of welders in electric motor driven or gas engine drive—air or water cooled—portable or stationary. Now you can have AC welding and AC power for repair or construction jobs away from power lines—may also be used as an emergency power source. Find out how you can get better, lower cost welding by mailing the attached coupon . . . no obligation, of course.

HOBART electrodes

Try them . . . a comparison will prove you can get more top quality welding per day. Hobart electrodes are made for every application of AC or DC welding. Tell us the type work you do and we'll send samples for you to try!



HOBART TROY OHIO **WELDERS**

Hobart Brothers Co., Box WJ-74, Troy, Ohio

"One of the world's largest builders of arc welding equipment"

CLIP THIS COUPON AND MAIL TODAY!

HOBART BROTHERS CO., BOX WJ-74, TROY, OHIO, Ph. 21223

Send information on the items checked below:

_____ Amp. Capacity ☐ Electric Motor or . . . ☐ Gas Engine Drive ☐ AC Power and AC Welding Combination ☐ Air Cooled ☐ Water Cooled ☐ Portable ☐ Stationary FREE ☐ Electrode

☐ FREE Welder's Vest Pocket Guide

Samples to be used on (type of work) _____

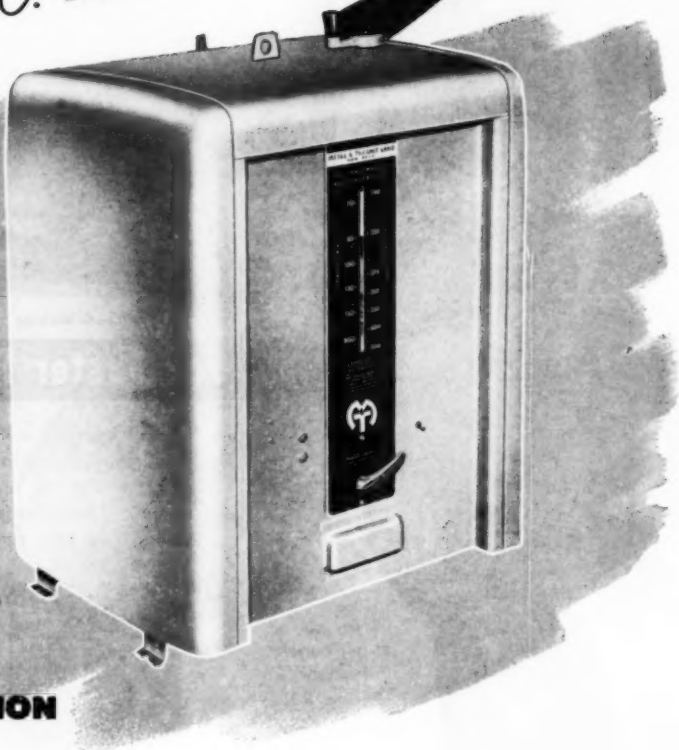
NAME _____ POSITION _____

FIRM _____

ADDRESS _____

HOBART WELDERS, ELECTRODES

For faster work at less cost—
M & T's New D.C. Rectifier Welder



INSTANT ARC

STABLE ARC

STEPLESS CURRENT CONTROL

SILICONE INSULATION

LESS WORKER FATIGUE

Your production is bound to increase when M & T's new DC Rectifier is on the job! Stable arc and instant reaction to changes in arc conditions mean stronger welds, fewer "patch-ups." There's no inductive time lag, either. Stepless current control, wide current range and absence of machine noise make for greater operator satisfaction and efficiency.

Maintenance is no problem whatever . . . Rectifiers and transformers are aircleaned by a reversible fan. There are no moving parts to wear out—the case can be removed for inspection easily, without disturbing primary lead. *Silicone insulation* protects against high temperatures, moisture, fumes and chemicals.

This 400 amp selenium rectifier is a standout in M & T's complete line of Welding Machines, Murex Electrodes and M & T Accessories. Write today for full information, or advice on any welding problem.

METAL & THERMIT CORPORATION 100 East 42nd Street, New York 17, N. Y.

MUREX ELECTRODES • ARC WELDERS • ACCESSORIES

You can make it yourself, like this...

or buy it from Mallory, like this...

and get a better tip for less money

"Home made" resistance welding electrodes can be expensive—not only because of the time they cost but also because of limited strength, poor conductivity and inadequate cooling.

Mallory standard stock electrodes are available in a wide range of designs. They can be adapted quickly to your special needs. Both single and double bend electrodes are cold formed, retaining maximum physical and mechanical properties...and with cooling tubes bent in place* to bring effective cooling close to the welding face. All this means long electrode life for uninterrupted production runs.

Don't resort to makeshift arrangements for your welding applications, no matter how special they are, until you check with Mallory. Holders and electrodes are available in a wide variety of shapes and sizes . . . standard parts that can be combined to handle practically any job. Ask your Mallory Distributor, or write us directly, for your copy of the new Mallory Catalog. See for yourself the almost limitless combinations of standard welding items that are quickly available

Expect more...

Get more from MALLORY

In Canada, made and sold by Johnson Matthey and Mallory, Ltd., 110 Industry Street, Toronto 15, Ontario

Resistance Welding Electrodes, Holders, Dies, Rods and Bars, Castings, Forgings

*Patent No. 2489993

Serving Industry with These Products:

Electromechanical—Resistors • Switches • Television Tuners • Vibrators

Electrochemical—Capacitors • Rectifiers • Mercury Batteries

Metallurgical—Contacts • Special Metals and Ceramics • Welding Materials

P. R. MALLORY & CO. Inc.

MALLORY

P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

For information on titanium developments, contact Mallory-Sharon Titanium Corp., Niles, Ohio

Follow this line to New Savings

The OXWELD Automatic Tracer is an accurate, economical motive power unit for oxygen-cutting machines. It is easy to set up and operate. No special tools are needed for templet cutting—they can be cut from VINYLITE plastic sheets with a knife or shears.

With an OXWELD Automatic Tracer

Trade-Mark

MAKES OXYGEN-CUTTING FAST, EASY and ACCURATE

Fast, clean, and accurate—that's how parts produced by automatic tracer-guided cutting machines come off the production line . . . Whether the job is cutting a wide range of simple patterns or intricate shapes, hundreds at a time or one piece—the OXWELD Automatic Tracer reproduces all templet designs exactly, and economically.

No need to allow for kerf in the size of templets—you merely set a dial to compensate for the kerf width of the nozzle in use. Parts are reproduced to tolerances ranging from plus or minus 7/32-in. to 1/16-in.—clean and smooth, and at high speeds.

Simple to set up—no special tools are required for making templets, they can be cut from VINYLITE plastic sheets with a knife or shears . . . The templet is simply mounted on the tracing table with masking tape. Your LINDE representative will be glad to discuss your needs, and help you determine the best setups for your oxygen-cutting operations. Start saving now—call him today for more information.

LINDE AIR PRODUCTS COMPANY
A Division of Union Carbide and Carbon Corporation
30 East 42nd Street UCC New York 17, N. Y.
Offices in Principal Cities

In Canada: DOMINION OXYGEN COMPANY
Division of Union Carbide Canada Limited

Linde Trade-Mark

The terms "Oxweld," "Linde," and "Vinylite" are registered trade-marks of Union Carbide and Carbon Corporation.

Published for the advancement of the science and art of welding by the AMERICAN WELDING SOCIETY

Editor
W. SPRARAGEN
Assistant Editor
B. E. ROSSI

The WELDING JOURNAL

Volume 33 **JULY 1954** *Number 7*

TECHNICAL PAPERS, ITEMS AND REPORTS

Special Problems in Structural Welding for Bridges, by Stewart Mitchell and Arthur L. Elliott 633
Current Welding Literature 642
Post High-School Technical Education—A New Trend, by Joseph Steinberg 643
Adhesive Bonding Complements Soldering and Brazing, by H. H. Simons 647
Automatic Horizontal and Vertical Welding of Field Erected Structures, by Amel R. Meyer .. 651
Packaging Welding Generators, by A. F. Fino ... 660
Fabrication and Welding of Steel Penstocks, by Robert F. Scott 663
Consumable Insert Method of Root Pass Welding, by Theodore A. Risch and Alfred E. Dohna 670

EDITORIAL PREVIEWS

Slag-Gas Shielded Welding 680

PRACTICAL WELDER AND DESIGNER

Magnesium Shell Racks—A Lightweight Job for Heliarc Welding 681

SOCIETY AND RELATED EVENTS

Society News 682
Second AWS Welding Show and Spring Meeting .. 683
Employment Service Bulletin 690
Tentative Program AWS National Fall Meeting 693
News of the Industry 698
New Products 706
New Literature 720
Personnel 722
Section News and Events 725
List of New Members 729
Abstracts of Current Welding Patents. 730
Index to Advertisers 732

WELDING RESEARCH SUPPLEMENT

Effect of Electrode Type in the Notch Slow-Bend Test, by William J. Murphy and R. D. Stout .. 305-s
Alloy Welds Deposited in "Unalloyed" Titanium Base Metal: Part I, by C. E. Hartbower and Daniel M. Daley, Jr. 311-s
Effect of Thermal Activation on Fatigue Life of Butt Welds, by A. M. Freudenthal and R. H. Heller 327-s
Study of the Cooling Rates in Flash Welds in Steel, by E. F. Nippes, Warren F. Savage, Gordon Grotke and S. M. Robelotto 339-s
The Significance of the Tension Test for Spot Welds, by E. R. Funk 363-s
Fatigue Tests of Welded Beam Connections, by Otto Graf 365-s

OFFICERS OF THE SOCIETY

F. L. PLUMMER	*President*
J. H. HUMBERSTONE	*1st Vice-President*
J. J. CHYLE	*2nd Vice-President*
R. S. DONALD	*Treasurer*
J. G. MAGRATH	*Secretary*
F. J. MOONEY	*Asst. Secretary*
S. A. GREENBERG	*Technical Secretary*

DISTRICT DIRECTORS

1—New York and New England	CLARENCE E. JACKSON
2—Mid-Eastern	D. B. HOWARD
3—Southern	ALFRED E. PEARSON
4—Central	J. H. BLANKENBUEHLER
5—Mid-Western	JEROME WELCH
6—Mid-Southern	J. E. DATO
7—Western	CLARENCE M. STYER

Published monthly by the American Welding Society. Publication office, 20th and Northampton Streets, Easton, Pa. Editorial and general offices 33 West 39th St., New York 18, N. Y. Subscriptions $7.00 per year in the United States and possessions; foreign countries $8.50. Single copies, nonmembers $1.00; members 75 cents. Entered as second-class matter January 5, 1932, at the Post Office at Easton Pa., under the act of March 3, 1879. Copyright 1954, by the American Welding Society. The Society is not responsible for any statement made or opinion expressed in its publications. Permission is given to reprint any article after its date of publication provided proper credit is given.

Largest Monel press roll ever built is fabricated by welding three 120° sections of plate together.

Sound from end to end

60 feet of welding in 2¾-inch-thick Monel shows "not the slightest evidence of porosity"

High speed paper mills pay a pretty penny for every minute of downtime. Yet, with an ordinary suction press roll, they have to ream thousands of holes and refinish the surface as often as every ninety days.

Right now several mills are operating Monel® rolls that have gone *more than three years without being touched.*

Welding a super press roll

Fortunately, fabrication of these super Monel press rolls presents no problem. Even in the case of giants like the one shown here, it's done simply and *soundly* with "130" Monel Electrodes.

This job was handled by the Youngstown Welding & Engineering Company. And it was a big job . . . *but literally!* Three 2¾-inch-thick by 38-inch-wide by 240-inch-long plates had to be joined to form the roll. Together they weighed nearly 12 tons.

700 lbs. of Electrode

The Youngstown people spent 500 hours welding this roll and used 700 lbs. of 3/16 inch diameter "130" Monel Electrodes for the three seams — 60 feet of 2¾-inch-thick weldment!

After each pass they made close inspection visually and with a flaw detection penetrant. A final check was made by machining the roll surface and boring a little less than half way through the welds at various spots.

No porosity

Youngstown reported this final check "did not reveal the slightest evidence of porosity." Welding with "130" Monel Electrodes had proved a highly satisfactory method of fabricating. The three welds are as strong as the parent metal and *just as corrosion-resisting* . . . that counts in the mills.

Maybe you have a welding job coming up, a job on Monel, Nickel or one of the other high nickel alloys. Use INCO Nickel Alloy Electrodes for best results. They're easy to work with. Write for the whole story in Technical Bulletin T-2, *Fusion Welding of Nickel and High Nickel Alloys.*

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street New York 5, N. Y.

Joining nearly 12 tons of Monel to form this giant press roll took 500 hours of welding and 700 lbs. of Inco "130" Monel Electrodes.

INCO TRADE MARK **Welding Products**
Electrodes • Wires • Fluxes

The WELDING JOURNAL

volume 33 July 1954 number 7

Special Problems in Structural Welding for Bridges

Bridge structures should be made of suitable steels, properly designed and fabricated with reasonable care

by Stewart Mitchell and Arthur L. Elliott

IT IS evident that the welding of steel for a particular purpose requires that the steel itself have the capacity to be welded under the imposed fabricating conditions to make it possible to design an economical structure that will perform satisfactorily under the expected service conditions. The more rigid the requirements the more costly the structure, so the specifications should not require anything that is not needed. To be specific, the choice of a suitable steel involves: (1) The properties and characteristics of the base metal, the weld metal, and the metal immediately adjacent to the weld after welding; (2) the design and fabrication requirements for members and connections; and (3) the practicable means of inspecting and testing needed in order to secure satisfactory performance under expected service conditions.

METALLURGY

The first of these factors comes under the general heading of "metallurgy," and it may be subdivided into: (1) the chemistry and structure of the base metal; (2) the effect on the metal of welding techniques (materials and processes controllable by the welder including preheating, rate of cooling, etc.); and (3) the service conditions that affect plasticity, which are: ambient temperature, strain rate, stress conditions (including repetitions, reversals, multiaxial stress) and the possibility and importance of "stress raisers" inherent in the design.

Generally speaking, the desirable characteristics for a structural steel weldment are strength with ductility that gives the required notch toughness, fatigue strength and soundness. Strength and ductility are seemingly incompatible requirements so it is necessary to seek an economic compromise suitable for the expected service. The metal must have a reasonable amount of strength but, withal, it must remain sufficiently plastic after welding to meet the expected service conditions. So far there is much uncertainty as to the practical and economical limitations to be placed on these conflicting properties in order to insure satisfactory performance.

This discussion is primarily concerned with that great majority of highway bridges of moderate span length which constitute such an important part of the highway. It may be of interest to note that 95% of all bridge spans on the California State Highway System are 100 ft or less in span length, and 85% of them are of less than 50-ft span length. The kind of steel which has been, and is being, used for almost all these bridges is that covered by the ASTM specification for A-7 structural steel. Low-alloy steel (A-242) and, less often, structural silicon steel (A-94) have been used in some few cases when these steels were readily available. Silicon steel is neither readily weldable nor is it readily obtainable at present. Therefore, this discussion of weldable bridge steel will be limited to structural carbon steel.

The objection to the use of A-7 steel for welding has been the lack of control over its carbon content. So far as the chemistry of structural steel is concerned, carbon is the primary element governing its weldability, hence a limit on the carbon content is desirable.

Stewart Mitchell is Bridge Engineer, Special Studies, and **Arthur L. Elliott** is Bridge Engineer, Planning, California Division of Highways Bridge Dept., Sacramento, Calif.

Presented at the AWS National Spring Meeting held in Buffalo, N. Y., May 4–7, 1954.

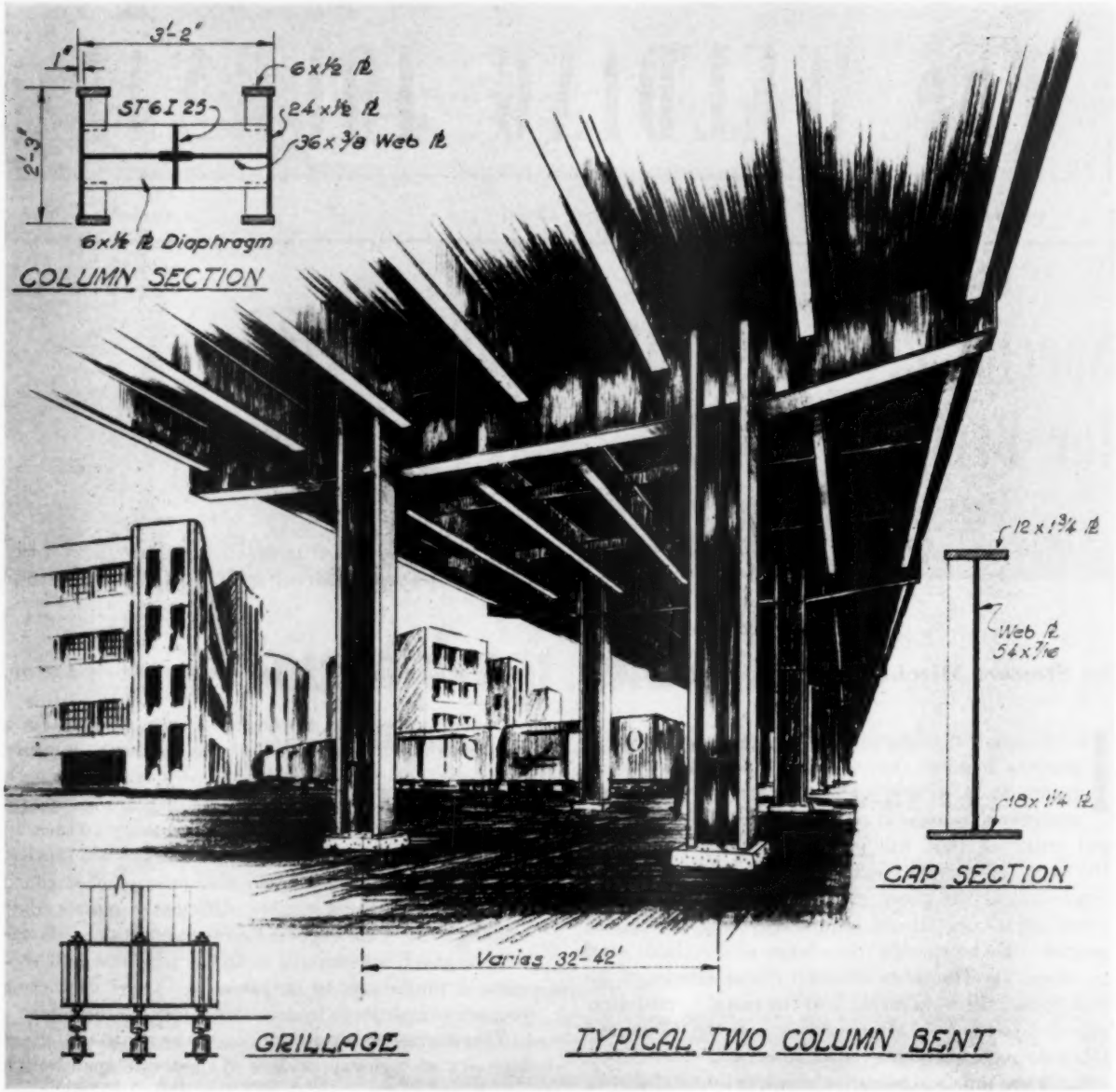


Fig. 1 Typical Two-Column Bent—San Francisco Structures. Lower flange plates for caps in some bents were up to 2½ in. thick

The problem is how to limit the maximum carbon content and retain the presently specified strength values for structural steel without incurring too much additional expense.

The best and most complete information on suitable structural quality steel for a given service has been gathered from the experience with welded ships. As the result of tests on the notch resistance of ship steel, involving actual steels from ships which failed in service, a revised specification for ship steel (A 131–50aT) has been adopted by ASTM). Quite recently, following conferences between representatives of the major steel companies, the AMERICAN WELDING SOCIETY and other interested parties, a specification for weldable steel for bridges and building was drawn up which has been tentatively approved by the Federal Government and by ASTM.* Likewise, certain welding techniques or procedures to be used in the fabrication of various types, grades and thicknesses of steel plates, prepared under the auspices of the WRC, have received general approval.† For convenience of reference, Table 1 lists the recommended procedure for carbon contents up to 0.30 carbon and for different plate thicknesses of the three grades of A131 and the modified A-7 steel.

If we refer to the specifications we find that the permissible carbon content for modified A-7 steel plates, with the exception of ½ to 1 in. thickness, is somewhat higher than for A-131 steel. It is understood that

* Interim Federal Specification Steel, Structural for Bridges and Buildings Type II. Approved by subcommittee II of ASTM Metals Committee A-1.

† Stout and Doty, *Weldability of Steels*, Welding Research Council, 1953 (Appendix).

Table 1—Carbon Content and Special Welding Techniques for Structural Carbon Steel and A.BS. Structural Steel

Steel	*Plate thickness, in.*	*Carbon content, %*	*Special treatment*	*Steel grade*
A7–50T	Up to 1/2, incl.	To 0.30, incl.	None	0.26 C max, Type II (AWS)
	1/2+ to 1, incl.	To 0.25, incl.	None	0.25 C max, Type II (AWS)
	1/2+ to 1, incl.	0.26 to 0.30, incl.	A or B	0.25 C max, Type II (AWS)
	1+ to 2, incl.	To 0.25, incl.	A or B	0.26 C max, Type II (AWS)
	1+ to 2 incl.	0.26 to 0.30, incl.	B or C	0.26 C max, Type II (AWS)
	2+ to 4, incl.	To 0.25, incl.	C	0.27 C max, Type II (AWS)
	2+ to 4, incl.	0.26 to 0.30, incl.	J	0.27 C max, Type II (AWS)
A131–50aT	Up to 1/2, incl.	To 0.25, incl.	None	A (no lim. on C)
	1/2 to 1, incl.	To 0.25, incl.	None	B (0.23 C max)
	1 to 2, incl.	To 0.20, incl.	None	C (0.25 C max)
	1 to 2, incl.	0.21 to 0.25, incl.	A or B	C (0.25 C max)
	2 to 4, incl.	To 0.25, incl.	C	C (0.25 C max)

Treatment: A, 100° F min, preheat and interpass temperature. B, No weld below 10° F, EXX15 or EXX16 electrode. C, 200° F min, preheat and interpass temperature. J, 100° F min, preheat and interpass temperature with EXX15 or EXX16 electrode, or 300° F min, preheat and interpass temperature with other electrodes.

the maximum carbon content for the A-7 plates was based on mill statistics; apparently certain mills could not produce steel with a 0.25 max carbon content without some difficulty. It seems that those who prepared the specifications for ship steel must have felt that the higher cost of maintaining a lower limit on the carbon could be justified in order to meet service conditions.

Along with maximum carbon content, the effect of other alloying elements that affect strength and ductility must be taken into account. Both A-7 (Type II) and A-131 specifications call for manganese in plates over 1/2 in. in thickness (A-7, 0.50/90 Mn; A-131, 0.60/90 Mn). As to mill practice, both specifications require 0.15 to 0.30 Si for rolled plates over 1 in. in thickness and call for "fine grain practice." The minimum yield point in both cases has been reduced from 33,000 to 32,000 psi, although it may be noted that plates for ships are not expected to be as thick as for bridge members.

The service conditions to be met in bridge and ship design may be compared as in the following paragraphs on the following points:

STATE OF STRESS

Stresses in bridge members or frames are usually simpler in character than in ships. The geometry generally affords less opportunity for notch effects or multiaxial strains such as occur at hatch corners. Lateral stresses in main bridge members, as well as stress reversals, are usually of relatively small magnitude. The action and nature of the stresses are usually more predictable and the possible magnitude of stress under all ordinary conditions is known to be within safe limits.

STRAIN RATE

Ships are subject to suddenly applied stresses and reversals of stress of large magnitude. In bridges, impact stress in certain members is important but the total stress under all loads occurring in normal service never exceeds the usual conservative design "working stress." Loads coming on a bridge produce a relatively gradual increase in stress compared to the buffeting received by ships.

TEMPERATURE

Extremes of temperature may be the same in both cases and it is evident that standard specifications should cover any and all situations. However, the effect of low temperature on steel is known to be temporary and bridges are subjected to extremely low temperatures for only a relatively short period while a ship may remain in arctic waters for a long time under severe stress conditions. Evaluation of probability factors such as frequency or likelihood of simultaneous occurrence of low temperatures and large stresses cannot be precise or definite but it is taken into account in setting up the value of the factor of safety to be used in the design. An example is the customary increase in allowable stress for the case of combined forces when their simultaneous occurrence will be infrequent or unlikely.

FABRICATION

The fabrication of bridge members, as discussed later, requires more welding of thin web to thick flange plates but more of the welding can be done under shop conditions. The fatigue strength of members built up of thick and thin plates is now being investigated but it is agreed that they require particular care in the use of heat and welding technique as well as in the quality of the metal in thick plates.

The following portions of this paper will outline the practice and experience of the California Highway Department in connection with designing and controlling the fabrication of built-up welded bridge members.

DESIGN AND FABRICATION

Next to metallurgy, the second important problem connected with structural welding for bridges is the proper design and fabrication technique to make the best use of the favorable features of welding.

It is not intended in this paper, to go into the subject of welding design for structures. It must be presumed that the design has been made adequately strong and that sections have been chosen which are well adapted to the welding technique. However, there are some

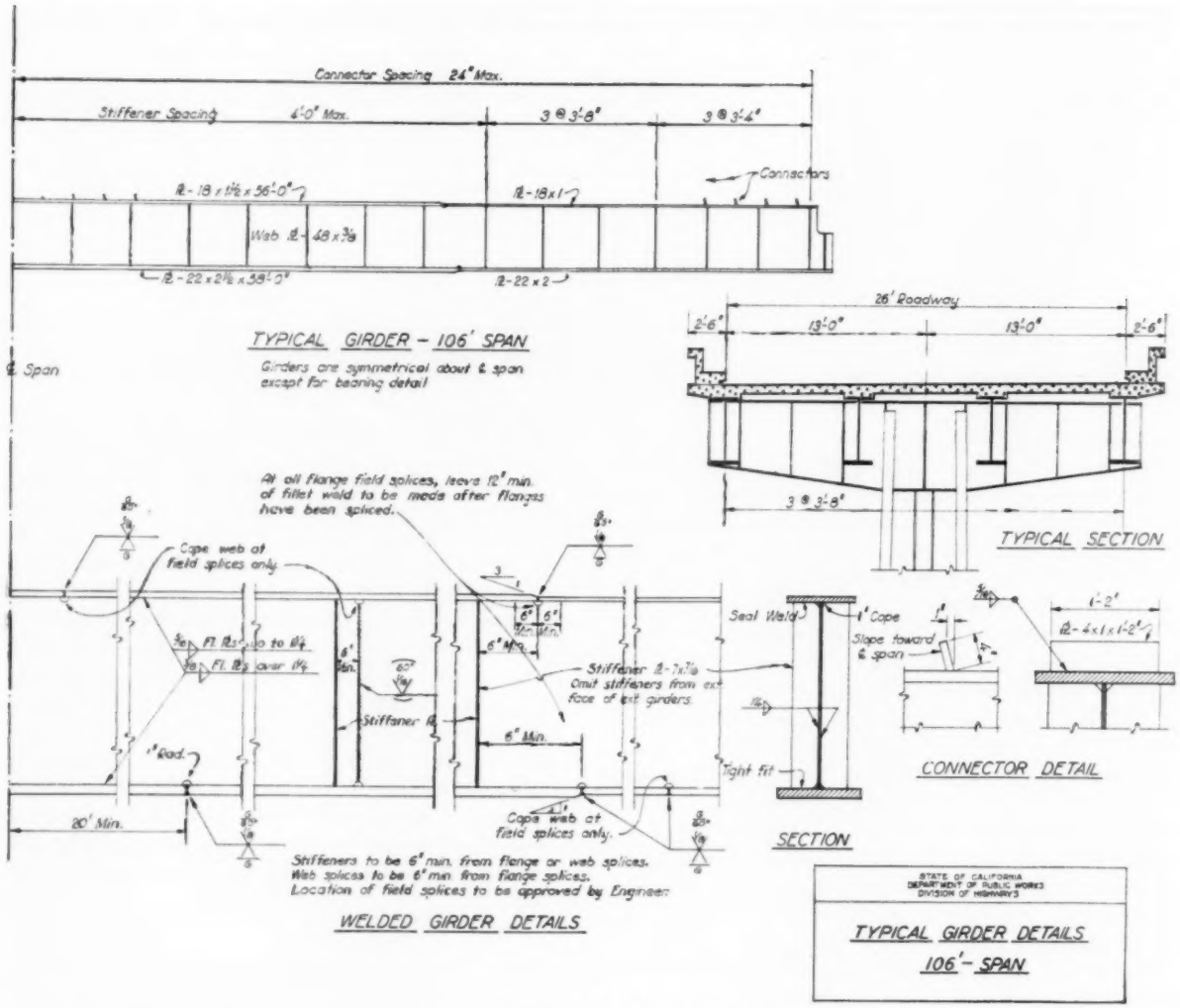

Connector Spacing 24" Max.
Stiffener Spacing
4'-0" Max.
3 @ 3'-8"
3 @ 3'-4"
Connectors
Web PL - 48 x 3/8
PL - 22 x 2
TYPICAL GIRDER - 106' SPAN
Girders are symmetrical about ℄ span except for bearing detail
26' Roadway
2'-6"
13'-0"
13'-0"
2'-6"
TYPICAL SECTION
At all flange field splices, leave 12" min. of fillet weld to be made after flanges have been spliced.
Cope web at field splices only
Stiffener PL - 7x3/8
Omit stiffeners from ext. face of ext. girders
Seal Weld
1" Cope
Slope toward ℄ span
1'-2"
PL - 4 x 1 x 1'-2"
CONNECTOR DETAIL
1" Rod
20' Min.
Tight fit
SECTION
Stiffeners to be 6" min. from flange or web splices.
Web splices to be 6" min. from flange splices.
Location of field splices to be approved by Engineer
WELDED GIRDER DETAILS
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
TYPICAL GIRDER DETAILS
106'- SPAN

Fig. 2 Typical 106 ft girder details

modifications worth mention which may be made in a structural design to provide easier fabrication.

Whenever possible the section should be planned so that the welding may be done by automatic machine. Experience has shown that the uniform quality of welding done by the automatic machines is such that the necessity for inspection is reduced to a minimum. It is obvious that a reliable process which consistently gives good results is of great value in simplifying inspection.

If it is not possible to set the work up for automatic welding, or where short lengths are being welded which do not warrant the use of the machine, then the work should be arranged so that semiautomatic welding can be used. This necessitates provision of adequate clearances so that the rather large welding electrode assembly can be gotten to the work. Provisions must also be made so that the welding can be done in a downhand position. This proper positioning is usually easier in shop assemblies where the work may be turned about so as to afford the most advantageous position. Therefore, whenever possible, the section should be planned so that the welding may be done in the shop.

Field welding does not in general match the quality of welding done in the shop. Therefore, every effort should be made to keep the field welding to a minimum and to arrange those field welds which are unavoidable so that they are in convenient positions. Wherever possible, all of the welding in main members should be done in the shop leaving only the welding of unavoidable splices and sway braces to be done in the field.

Again comparing to ship construction—in ships, because of the greater number of units to be joined in the field, the niceties of shop welding are often not possible and inconvenient welding positions are often unavoidable.

DISTORTION CONTROL

After the control of the welding operation itself, the most important consideration, of special concern in structural welding, is the control of distortion. In many other types of welding the creation of locked-up stresses may cause cracks or raise serious difficulties, but, in structural work owing to the length and slender-

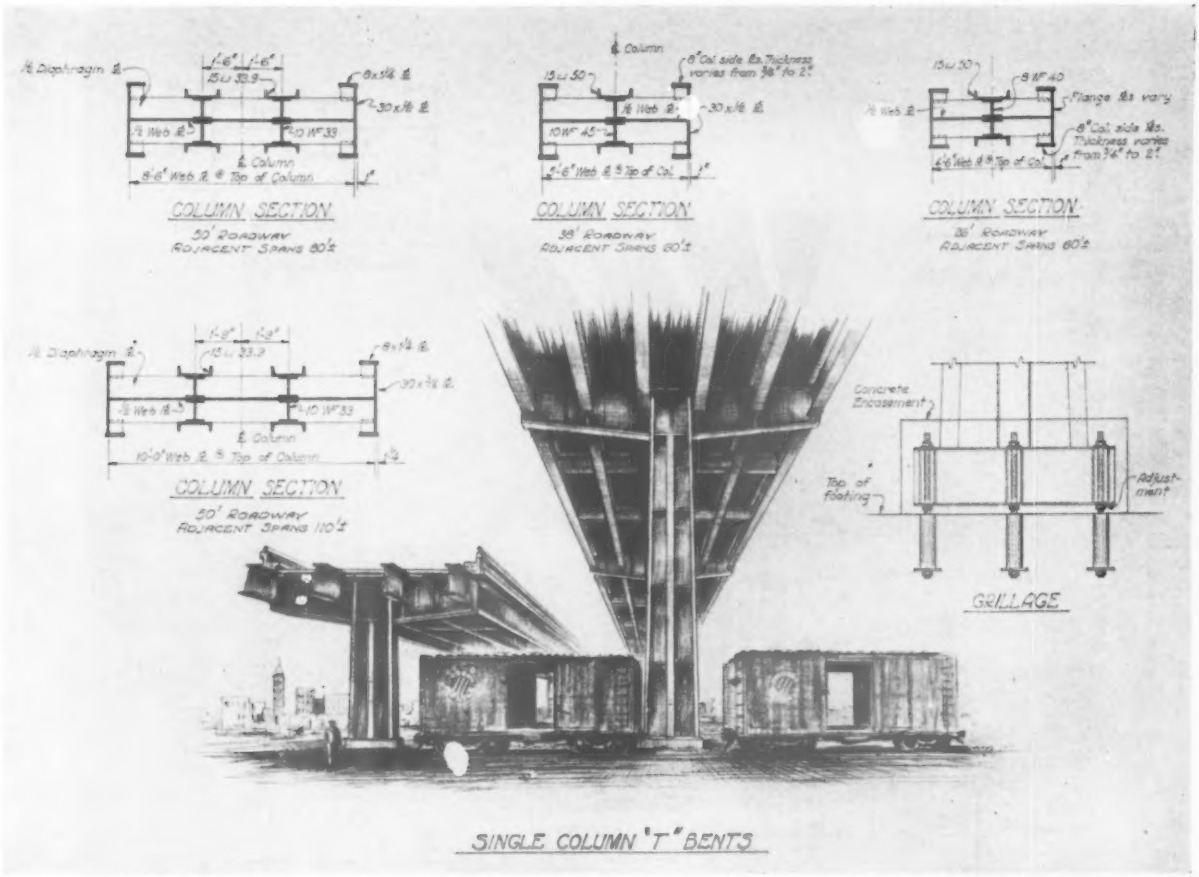


Fig. 3 Typical single column "T" Bents—San Francisco Structures. The unsymmetrical welding of the corner plates complicated the distortion control

ness of the members, locked up stresses usually demonstrate themselves in the form of distortion.

Distortion cannot be tolerated and it is essential that proper techniques and the welding sequences be used to prevent twisting and warping. However, because of the many factors involved, all of which have a bearing on the success of the welding operation, what may work for one type of member will not necessarily work for another. It is not possible to set up definite rules of procedure and to say that if this or that sequence is followed no distortion will result.

For instance, on some of the heavy cap girders for the San Francisco welded structures, built in 1952, (Fig. 1) web plates $^3/_8$ and $^1/_2$ in. in thickness and 54 in. wide were welded to flange plates as thick as $2^1/_2$ in. in order to produce built-up welded girders over 75 ft in length.

The bottom flange of the cap girder was made up of five different plates—$1^1/_4$ in. thick. In the welding sequence the three center plates were butt welded together and then were welded to the web. After this, the two end plates were first butt welded to the flange plates and then welded to the web plate. The welding of the flange to the web was done simultaneously on each side with the welders about 12 in. apart.

The beam had an irregular shape (a tapered section on each end outside of the column support), and no difficulty was experienced with distortion. The short lengths and heavy plates used probably had some influence on the success of this sequence of operation.

On the other hand for an overhead structure on the East Shore Freeway in the San Francisco Bay area a 106-ft beam 53 in. deep was built up of a web $^7/_8$ in. thick and flanges 3 in. thick (Fig. 2). In this girder, the welding was done one side at a time and the beam allowed to cool after welding each side.

The flange plates were butt welded out of three separate plates and the web plate was fabricated from two sections 37 and 70 ft long. The two flanges and the web plate were then assembled in a jig, and tack welded. The beam was then rolled over to a 35-deg angle and, making 14 passes on each side, the fillet welds were made one side at a time. The 4-hr continuous welding on the beam as well as the preheating operation itself caused considerable unequal expansion within the beam. This produced about $2^1/_2$ in. of temporary camber. After 8 to 10 hr cooling, the beam straightened out and it was possible to turn it over and make the fillet weld on the other side.

Thus, in these two instances one beam was fabricated by simultaneous welding on both sides using a fairly thin web plate and short flange plates while in the other case with a somewhat thicker web plate and flange

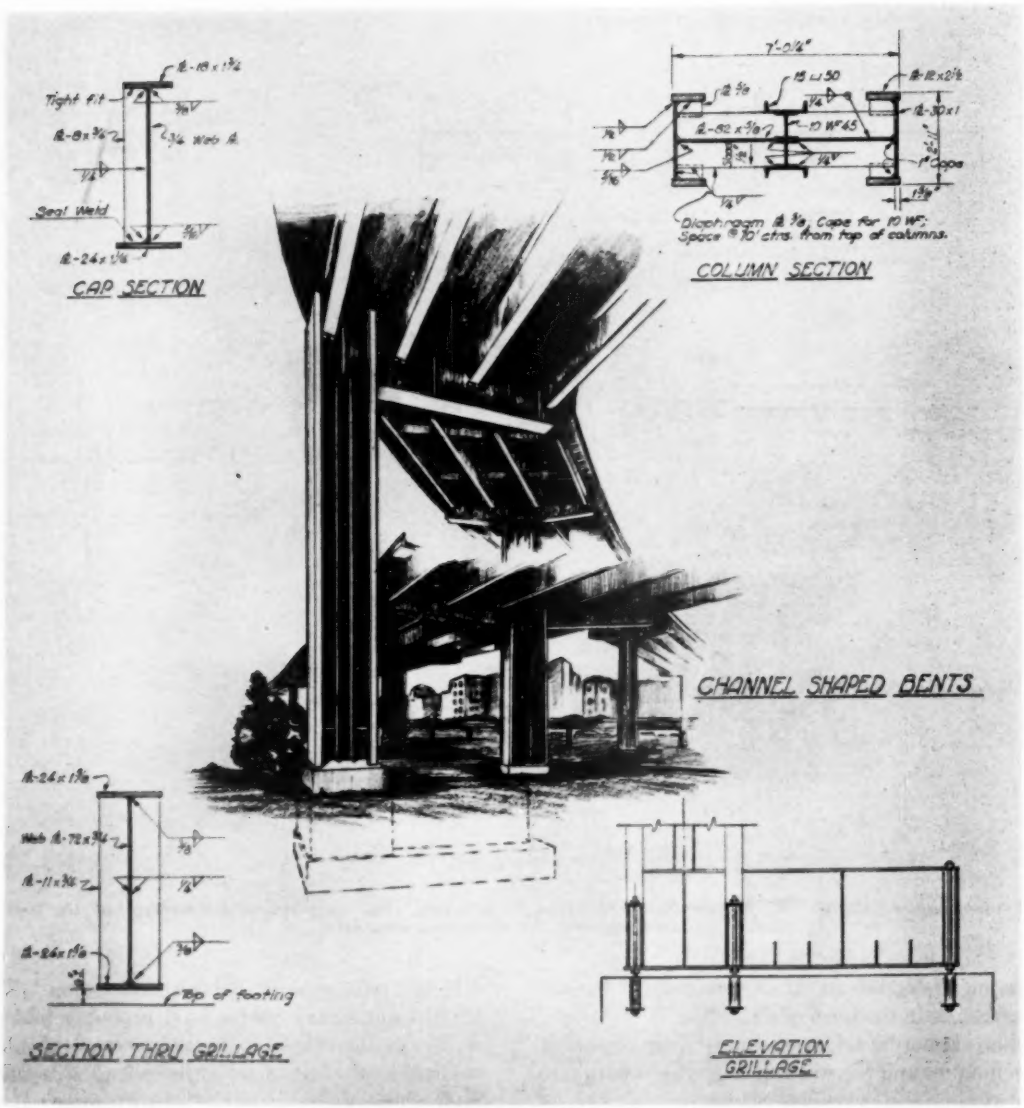


Fig. 4 Unsymmetrical "C" Bent—San Francisco Structures

plates, the fillet welds are successfully placed one side at a time.

Two things become very evident in the welding of large and long structural members. First, special study must be given to the procedure for each individual case. Second, prescribing a welding sequence is only a portion of the problem when it comes to actually fabricating the beams in the shop. Contrasted with riveted practice, the concept of fabrication by welding is entirely different. Many jigs, clamps, special holding devices, and straightening arrangements are necessary to successfully fabricate a large welded beam. For the 106-ft beam just mentioned the shop built a moveable cradle assembly with 8-ton jacks provided at intervals for holding the web and flanges in contact as well as other jacking arrangements to provide for lateral adjustment. This incidental equipment along with the installation of the automatic welding machine itself is a far cry from the shop equipment normally used for riveted assemblies. These different methods of fabrication and the required conversion of equipment have been one factor in the reluctance of some large fabricating shops to wholeheartedly endorse a change to all welded construction. On the other hand, once the conversion is made and familiarity gained with this type of work, a price benefit is felt and the economies of welded construction may be realized.

Returning to the matter of distortion and locked up stresses: In long slender structural members, the locked up stresses usually dissipate themselves in the form of distortion. Nevertheless, the sections are usually heavy enough so that in local areas, if proper precautions are not taken, cracking does result in the welds themselves. The fact that the members are long and flexible does not mean that the problem of planning to avoid cracking in the weld is any less acute. Also the

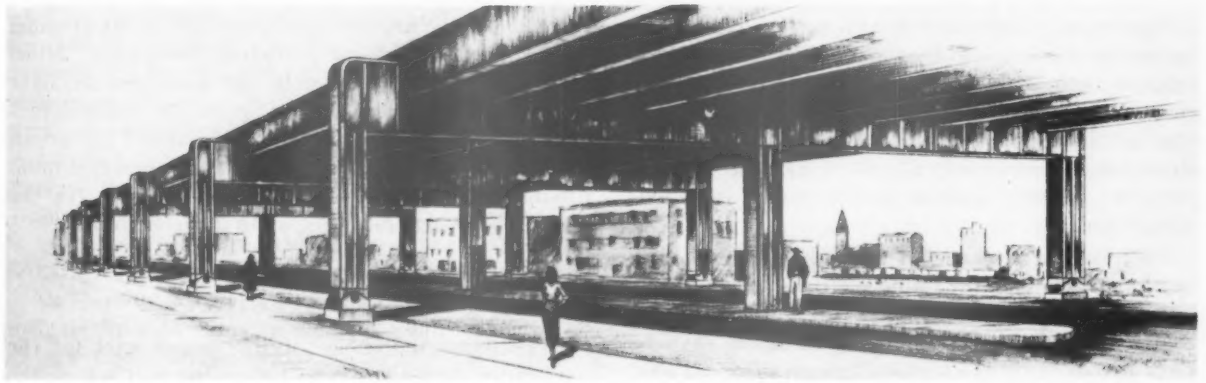


Fig. 5 Typical three-column bents—San Francisco Structures

absence of distortion is no guarantee of freedom from locked up stresses. Distortion may sometimes be prevented by prebending but stresses may still be present. The welded assembly also may be too stiff to distort but stresses may crack the welds.

Along with other considerations, it is, of course, of prime importance that the welding machine itself be carefully controlled to insure the proper penetration and to produce a sound weld which does not crack.

PREHEATING AND POSTHEATING

In both distortion and elimination of cracking in the welds themselves, the subject of preheating is still being extensively studied. Because of the tendency of the welding operation itself to heat the base metal ahead of the actual placing of the weld metal, preheating is generally not necessary in material under $1^1/_2$ in. thick. When working with thicker material, however, the heat of the arc itself is not sufficient to warm a very large area around the weld, and as soon as the welding machine has passed, the large volume of cold parent metal next to the weld chills the outer edges of the weld and pulls the edges before the center has solidified. This results in a visible or a submerged crack in the heart of the weld itself. Therefore, in these heavier sections preheating is essential.

The application of postheating in general depends upon the comparative thickness of the plates in the joint. Where a thin plate has been welded to thick plate, under normal conditions, the heat will stay in the heavy plate, and it will cool slowly, whereas the thin plate will cool rapidly, possibly chill the weld and cause an internal crack. The purpose of preheating or postheating, therefore, is to raise the temperature of the metal high enough so that the weld metal and adjacent base metal will not cool too quickly but will slowly return to its normal temperature at the same rate as the parent metal. Because of the size of the members, stress relieving at 1100–1250° F, although it provides a satisfactory solution to the internal cracking problem, is impractical. For unsymmetrical sections in which heavy and light plates are combined, such as in steel columns, a higher preheat temperature is necessary. (Figs. 3 and 4). For this purpose 400° F was set as a reasonable maximum.

In the case of the 106-ft beam, the plates were preheated to a minimum metal temperature of 300° F. The metal was kept at this temperature by two gas torches and one large kerosene torch. After the weld had been made, the cooling was slowed by clamping 6-in. strips of asbestos board against the steel. In this manner the cooling time was extended to 10 hr. Here again is a point where welded fabrication requires special treatment—after taking 4 hr to make one fillet

weld it was necessary that the work stand for 10 hr before anything additional could be done.

In heavy welded assemblies, such as bearing shoes, where the members are not flexible enough to allow distortion to relieve the locked-up stresses, unless prevented, the stresses will cause cracking in the weld itself. Stress relieving is of assistance in combating some of this cracking, however it does not provide the complete answer. If the sequence of welding is not proper, it is entirely possible to develop a situation in which the final welds will cause such extreme shrinkage that it will be impossible to make a weld satisfactorily without contraction cracking.

The answer to welding these heavy grid sections such as column bases and bearing assemblies, lies either in developing a sequence in which there are no locked up stresses or else in which the locked up stresses may be relieved as the welding progresses. If sequence alone cannot solve the problem, then the construction of the unit in subassemblies which may be made individually stress free and then finally all welded together will complete the assembly without including any distortion-caused stresses.

To cover the requirement for preheating and postheating if necessary, the California Bridge Department specifications now read as follows: "If necessary, the contiguous areas about a welding operation shall be preheated and held at a temperature not to exceed 400° F during the welding operation. Also if necessary the lighter parts shall be postheated, holding the temperature of contiguous parts substantially equal while the weld is cooling."

This specification does not grade the required preheating temperature on the basis of plate thickness; however, shop inspectors of the California Testing and Research Laboratory, who do the inspection during the fabrication steel for California State Highway Bridges, are following the AWS Metallurgical Table on Preheating as a guide until a range of recommended temperatures is included in the AWS Specifications.

The Welding Research Council book on *Weldability of Steel*, already referred to, deserves special mention as a comprehensive addition to knowledge in this field. It discusses the weldability characteristics of various steels from the standpoint of chemical content, physical characteristics, thickness of the material and the type of service to which it will be subjected. The subject of preheating is discussed quite thoroughly and recommendations are made for degree of preheat for various carbon contents and thicknesses of plate. The use of the submerged arc process of welding and the use of low-hydrogen electrodes are additional factors which along with preheating and postheating are useful in the control of distortion.

So far as present knowledge goes, there is little doubt that the use of low-hydrogen electrodes is very effective in assisting to eliminate cracking in the weld. The California specifications require plates, making up main-stress-carrying members over one inch in thickness, to be welded either by the submerged-arc process or with low-hydrogen electrodes. Where both of the plates being welded are less than one inch in thickness, the welding is to be done in conformance with Section 4, article 401 of the Specifications of the American Welding Society, in lieu of requiring the use of low-hydrogen electrodes.

In order to gain full benefit from the use of low-hydrogen electrodes, they must be absolutely free of moisture. This means special care to store the rods and keep them dry until use. When properly used, the low-hydrogen rods reduce one more cause of cracking.

The California specifications are perhaps somewhat more severe in their requirements than the AWS Specifications or the recommended procedure in the Welding Research Council book previously mentioned. However, in so far as possible the specifications have tried to refrain from setting up specific welding procedures and minimum preheat temperatures for various thicknesses of plate, but instead, within specified minimum requirements, to specify results and leave the actual degree of preheating up to the fabricator.

INSPECTION

Presuming the choice of the proper steel for the structure, that the design makes the best use of the welding techniques, that the welding sequences and fabrications are worked out so as to minimize distortion and locked up stresses, then comes to the final step, the inspection—inspection to prove whether all these efforts have resulted in a good job.

The California Division of Highways, in starting a series of major welded steel structures which have so far totaled over 25,000 tons, found that in setting up inspection controls there was little precedent to draw upon.

Until a few years ago, the use of welding in bridge structures was confined to secondary members, incidental bracing and emergency repairs. During this period the inspection of structural welding was limited to qualifying the welders and following their work by close supervision of qualified inspectors. However, with the use of welding as the major joining agent in main members, it became evident that some method of inspection other than mere observation of the process was necessary. A further complication is, of course, that any testing method must be nondestructive of the structural element itself. The field of nondestructive structural weldment inspection was, therefore, thoroughly reviewed. As a result of this investigation, visual inspection was supplemented by the use of penetrant dye, trepanning (the taking of small cores from the weld itself), and hardness testing during fabrication followed by radiographic inspection of the completed weld. In cases of doubt as to the metallurgical structure, inspection of the grain structure was made through use of microphotographs.

The specifications provided that the testing would be performed without cost to the contractor, and was covered by the following two sentences, "All welds shall be subject to nondestructive testing by the Engineer. Such nondestructive testing will be performed without cost to the contractor."

The older precautions were taken in addition to the new methods of inspection. The welders were all prequalified both in the making of shop and field welds in accordance with the AWS qualification tests. Physical tests were also run on the run-over tabs which are used at the end of the welding sections on runs of the automatic machines. Very careful visual inspection was also given to the entire procedure by capable inspectors.

One very important step in the inspection of welded work is a very thorough understanding and cooperation between the inspector and the fabricator during the fabrication. It is essential that the fabricator be interested in obtaining a satisfactory job, that he understand the inspection methods, and that he give his cooperation during the fabrication operation so that a good job may be obtained.

Shop superintendents are usually quick to grasp the fact that it is cheaper in the long run to work closely in cooperation with the inspectors and to avail themselves of the results of the inspection methods. Adapting their methods or changing their procedures to correct sources of defects saves expensive chipping out to re-do welds. Management, however, with its eye on production and its judgment based on yardsticks established for riveted fabrication, often does not show this willingness to cooperate or the desire to benefit from the results of the inspection reports.

After the weld is completed visual inspection can reveal much as to its quality. To the experienced inspector the size and the shape of the weld will often reveal the location of craters, slag inclusions or subsurface porosity. The use of penetrant dye is also helpful in the detection of cracks. It also assists in determining the limits of subsurface defects during the repairing process.

Trepanning is used primarily with fillet welds to determine the extent of the penetration.

The hardness of the weld is also measured as a determination of a factor in the quality of the weld. Hardness testing in the shop is not as accurate as under laboratory conditions but it does serve as a guide with which to supplement laboratory tests on other specimens.

Extensive use is made of radiographic inspection. Making radiographic plates is slow and expensive. It soon becomes obvious when working with automatic welders that there is no necessity for making radiographic plates of all of the welding. After the machine has been properly regulated and by inspection of sections of the weld has proved that it is making a satisfactory fillet weld, there is little to be gained in making large numbers of additional radiographic exposures. California, therefore, developed the practice of using the radiograph during the time when a machine was being set up for the work, but after it was in proper operation, additional exposures were made only to prove the presence of an already suspected defect or if there were a change in the setup of the machine.

It is the policy to radiograph all butt welds in tension flanges. All of the compression butt welds are also radiographed if the tension welds are found to be faulty, however, if the tension butt welds prove to be satisfactory only one out of every four compression flange butt welds is radiographed.

It is important to note that the experience of the radiographic technician is of vital importance in obtaining a good set of pictures.

In the interpretation of the radiographic pictures it is difficult to distinguish the character and seriousness of the defects pictured. In so far as the California standards are concerned, they have maintained that to be acceptable a weld must be free from any form of cracking in the weld or weld area. There is no objection, however, to the weld containing a slight oxide or slag inclusion or small gas pocket provided they are within tolerances indicated by the American Welding Specifications. Unacceptable welds include those containing a chain of slag inclusions or too much porosity, those with poor fusion or lack of fusion, those containing any type of crack. All of these require repair before being accepted. This degree of defect is difficult to detect from the radiographic films however.

Such standards of acceptance must necessarily be on the arbitrary side. When any irregularity on the radiographic film is regarded as a defect and repair is ordered, it becomes obvious that anything less than a perfect weld is unacceptable. Although there are degrees of defects, some of which do not render the weld unacceptable, a better means of interpretating the radiographic pictures is needed to determine which welds may still be acceptable with some slight defects in evidence. Radiographic inspection, although it is the best method now available, because of its expense, its need for a skilled operator, and the difficulty in qualitatively analyzing the results, still leaves much to be desired.

There are, however, certain secondary results of the use of radiographic inspection which are very beneficial to the quality of the job. These benefits are primarily in the effect of radiography on the welding operator. The use of this method of inspection which reveals every defect, often making small defects look just as bad as serious ones, tends to induce the operator to exercise additional care. Also, by seeing the defects on the film, along with a discussion of their cause, the work habits of most welders are improved.

Radiographic work has been done both with X-ray equipment and with gamma rays using as their source either radium or cobalt 60. High energy cobalt 60 is the most used at the present time. The pictures are recorded on file $3^1/_2$ to $4^1/_2$ in. wide and 16 to 17 in. long. The cost of the pictures started out very high at about $26 per plate. As it came into greater use, how-

ever, the costs have dropped to about $7.50 per plate. Occasionally under excellent conditions plates may be taken for as little as $2.00.

The actual radiographic inspection work is done by various commercial laboratories and on these specific jobs in San Francisco the radiographic inspection averaged about $0.16 per ton of welded steel construction.

CONCLUSION

Improper design or choice of steel and carelessness in fabrication should not be held against welding any more than it would be in other types of construction. Fractures in ships apparently started more often from notches arising from poor design details than from defective fabrication, but care in both operations is essential. Knowledge, experience and judgment are the only insurance against costly fabrication or failure in service. Lack of proper equipment and experienced personnel may be an economic factor in the development stage of any procedure. It perhaps has been so in the case of welded bridges, but having been generally accepted, designers or steel men should not be influenced by a few fabricators who fail to keep up with the times.

Whether the presently adopted steels or the techniques used in fabrication are the best from the standpoint of economy or safety can be determined only from experience. Much can be learned from actual structures just as much experience has been gained from ships. Load tests of existing bridges indicate that actual stresses as great as the "working stress" used in design can occur only infrequently under the heaviest traffic. It is to be expected, therefore, that failures of existing bridges, should they occur, will be the result either of improper weldments that have introduced serious "stress raisers" or embrittlement of the steel. At least in moderate climates, it seems evident that the engineer has little to fear from welding if the structure is designed and fabricated with reasonable care under present adopted specifications for manufacturing and fabricating structural steel for bridges.

Bibliography

Epstein, Samuel, "Notch Resistance of Carbon Steel Ship Plate," Regional Technical Meetings, AISI, 1951.

Sweeney, E. F., "Evaluation of Brittle Failure Research," THE WELDING JOURNAL, 32 (1), Research Suppl., 1-s to 13-s (1953).

Boberg, I. E., "The Use of Structural Quality Steel in Pressure Vessels," *Ibid.*, 32 (8), Research Suppl., 413-s to 416-s (1953).

Shank, M. E., "A Critical Survey of Brittle Failure in Carbon Plate Steel Structures Other Than Ships," Welding Research Council. *Bull. No. 17*, January 1954.

Beaton, J. L., and Jonas, P. G., "Structural Weldment Inspection," California Division of Highways Testing & Research Laboratory, ASCE, March 1953.

Stout, R. D., and Doty, W. D., "Weldability of Steels," Welding Research Council, 1953.

Cape, G., and Jehu, L., "Distortion Control in Structural Fabrication," THE WELDING JOURNAL, 31 (11), 1009–1016 (1952).

Hollister, L. C., "California's All-Welded Viaduct Points Way to Improved Design," *Civil Engr.*, 22, No. 9, 180 (September 1952).

Binder, R. W., "Sequence and Continuity Mark Modern Welding Practice," *Ibid.*, 22, No. 9, 186 (September 1952).

CURRENT WELDING LITERATURE

Aircraft Manufacture. Gas Welding Pays Off for Aircraft, T. A. Dickinson. Welding Engr., vol. 39, no. 3 (Mar. 1954), pp. 34–35.

Aircraft Manufacture. Here's How Ryan Aircraft Speeds Fusion Welding With Inert Arc Process. Industry & Welding, vol. 27, no. 3 (Mar. 1954), pp. 72–74, 77–78, 80–81.

Aircraft Manufacture. Shielded-Arc Techniques Dominate Ryan Fusion Welding. Machy. (N. Y.), vol. 60, no. 7 (Mar. 1954), pp. 180–185.

Aluminum and Aluminum Alloys. Progress and Future of Structural Aluminium, C. Marsh. Light Metals, vol. 17, no. 192 (Mar. 1954), pp. 92–93.

Beams and Girders, Stresses. Effect of Plastic Yield in Bending on Mild Steel Plate Girders, A. Lazard. Structural Engr., vol. 32, no. 2 (Feb. 1954), pp. 49–59; (discussion) 59–66.

Boiler Manufacture. Better Boilers by Automatic Set-Ups. Welding Engr., vol 39, no. 3 (Mar. 1954), pp. 27, 48.

Brazing Beryllium. How to Braze Beryllium, M. J. Zunick and J. E. Illingworth. Matls. & Methods, vol. 39, no. 3 (Mar. 1954), pp. 95–97.

Brazing Silver Alloy. Testing High-Strength Silver-Brazing Alloys, K. M. Weigert. Welding Engr., vol. 39, no. 3 (Mar. 1954), pp. 44–45.

Bridges, Steel Arch. Inclined-Arch Bridge Spans 250 Ft T. C. Kavanagh and C. Piccone. Eng. News-Rec., vol. 152, no. 8 (Feb. 25, 1954), pp. 46–47.

Bridges, Steel. Welding for Repair and Strengthening of Bridges, P. V. Pennybacker. Western Construction, vol 29, no. 1 (Jan. 1954), pp. 77–80, 84.

Buildings, Welding. Meet "Fish Bowl," H. J. Miller. Welding Engr., vol. 39, no. 3 (Mar. 1954), pp. 28–30.

Buildings. Welding Tall Building to Take High Wind Loads, A. Oboler. Eng. News-Rec., vol. 152, no. 6 (Feb. 11, 1954), pp. 38–39.

Cement Plants, Maintenance and Repair. Weld-Surfacing of Cement Mill Equipment, W. M. Davis. Rock Products, vol. 57, no. 2 (Feb. 1954), pp. 114, 116.

Compressors, Exhausts. Gas Engine Manifolds Are Fabricated with Automatic Welding. Machine & Tool Blue Book, vol. 49, no. 3 (Mar. 1954), pp. 170–172, 175–176.

Containers, Aluminum. Fabricated Food Containers. Welding & Metal Fabrication, vol. 22, no. 3 (Mar. 1954), pp. 90–91; see also Light Metals, vol. 17, no. 192 (Mar. 1954), pp. 80–81.

Containers, Manufacture. Use of Solder Paint in Container Manufacture, G. Taylor. Sheet Metal Industries, vol. 31, no. 324 (Apr. 1954), p. 288.

Copper. Nitrogen-Arc Welding of Copper, K. Winterton. Brit. Welding J., vol. 1, no. 2 (Feb. 1954), pp. 87–90.

Copper. Nitrogen-Arc Welding of Copper, E. Davis and C. A. Terry. Brit. Welding J., vol. 1, no. 2 (Feb. 1954), pp. 53–64.

Earthmoving Machinery, Maintenance and Repair. Automatic Submerged Arc Saves 60% when Rebuilding Worn Equip-

(Continued on page 669)

Post High-School Technical Education—A New Trend

Training of technicians on the subprofessional level at the New York City Community College to provide education and training in applied arts such as welding

by Joseph Steinberg

HISTORY OF THE COLLEGE

IN THIS, the age of specialization, evolution that has changed the thinking of the world is taking place not only in Industry but in Educational circles as well. Up to about ten years ago the graduate engineer was both designer and technician, causing a shortage of trained personnel in the technology fields. The challenge of this evolution had to be met. New York State, realizing the need of Industry for trained technicians on the subprofessional level, instituted, by an act of the legislature in 1946, five Institutes of Applied Arts & Sciences throughout the State of New York on a 5-year pilot plan basis. The purpose of this was to provide "Education and training in applied arts, crafts, retail business management, subprofessional and technical skills through curricula not to exceed two years in length, including related work in arts and sciences and other subjects essential to the general welfare and understanding of students."

The New York City Community College of Applied Arts & Sciences was one of the five Institutes originally established and was under the sole support of the State of New York until Sept. 1, 1953, when the City of New York established the Institute as a Community College with partial support by New York State and New York City tax funds. Scientific and technological changes have increased the possibilities for employment at the technician's level. For every trained professional it is estimated that industry and business demand five to seven trained technicians. It is the purpose of the College to provide education which will enable graduates to qualify for a series of related jobs within their chosen field at the technician level. The fundamental purpose of American Democracy and the American way of life are stressed in both technical and general education at the College.

The challenge of the evolution was met! Faculty, buildings, equipment, curriculum and students are organized and in eight short years the College has arrived. It is real, vibrant and spirited. It is sturdy and strong, yet flexible enough to meet the ever-changing needs at its level of instruction. The college has 15 different courses; 2300 full-time day students; 1700 extension students of which 50% are on a matriculating basis; an expert faculty of 150 in the day school and a faculty of 118 in the extension division; two large modern buildings; the most modern of laboratories, shops, drafting rooms, classrooms, and offices having an inventory value of over $2,000,000.

The construction Technology Department of the college is one of four technologies that educate students on the sub-engineering level, the three other Departments being Mechanical Technology, Chemical Technology and Electrical Technology.

CONSTRUCTION TECHNOLOGY DEPARTMENT

The Construction Technology Department has a student population of 270 full-day time students and 279 Extension Division students. The curriculum of the Department is so integrated and designed as to enable the graduates to become effective and valuable assistants to architects, engineers, estimators and to the Construction field in general, through a knowledge of general construction, theory, methods, and practical application. The student is not educated to accept employment as a tradesman in any manual type of position. The course is open to high school graduates who, upon graduation, receive an Associate in Applied Science Degree in Construction Technology. The Department has an Advisory Committee from Industry representing Engineers, Architects, Contractors, Labor, Steel Fabricators, Steel Detailers and Estimators.

Joseph Steinberg is Head, Construction Technology Department of the New York City Community College of Applied Arts and Sciences, 300 Pearl St., Brooklyn 1, N. Y.

Presented at the National Spring Meeting, AWS, held in Buffalo, N. Y., May 4-7, 1954.

The Advisory Committee is consulted on curriculum changes, needs of industry, employment of graduates and other matters pertaining to the Construction field. They are a capable outstanding group of men and most cooperative.

The Curriculum of the Construction Technology Department is as follows:

Subject Title	*Class Hr*	*Lab Hr*	*Credit*
FIRST SEMESTER			
Mechanics	3	..	3
Projection Drawing	1	2	2
Construction Techniques	2	6	4
Basic Communication Methods	2	..	2
Mathematics	5	..	5
Sociology	3	..	3
	16	8	19
SECOND SEMESTER			
Elementary Surveying	1	2	2
Structural Calculations	2	..	2
Small House Architecture	..	6	3
Construction Methods and Practice	3	2	4
Strength of Materials	3	..	3
Writing and Thinking Techniques	2	..	2
Physics	3	..	3
Psychology	2	..	2
	16	10	21
THIRD SEMESTER			
Construction Estimating	2	2	3
Building Utilities Services	3	..	3
Route Surveying	1	2	2
Structural Steel Design	4	2	5
Industrial Architecture	..	6	3
Effective Speaking	2	..	2
Industrial Relations	2	..	2
	14	12	20
FOURTH SEMESTER			
Structural Steel Detailing	2	4	4
Structural Steel Fabrication	2	3	3
Highway Construction	2	..	2
Contracts and Specifications	2	..	2
Reinforced Concrete Design	5	..	5
Applied Communications Procedures	2	..	2
American Government	3	..	3
	18	7	21
Total Class Hours	64		
Total Lab Hours	37		
Total Credits	81		

Successful completion of the curriculum leads to an Associate in Applied Science degree. It should be noted from the curriculum that every effort is made to educate the student through a proper sequence of subject courses. The design portion starts with Mathematics and Mechanics (Statics of Physics), proceeding through Structural Calculations, Strength of Materials, Physics (Heat, Light and Sound), Structural Steel Design and Reinforced Concrete Design.

The construction portion incorporates Construction Techniques, Elementary Surveying, Construction Methods and Practices, Construction Estimating, Building Utilities Service, Route Surveying, Highway Construction and Contracts and Specifications.

The Architectural Drafting includes Projection Drawing, Small House Architecture and Industrial Architecture.

In the fourth semester, based upon the design sequence through Structural Steel Design, the student is taught to detail steel for fabrication and the actual fabrication of their details. The curriculum is rounded out with courses in Social Science and Communication Arts and Skills. There is no specialization by a student in any area of the curriculum; the student must take and pass each of the subject courses in a semester before going on to the next semester. However, in the Extension Division, a student can take a special sequence of courses but does not receive an Associate in Applied Science degree. He does receive a certificate upon completion.

The areas of the Construction Technology Department curriculum to be stressed in this paper are the courses in *Structural Steel Detailing* and *Structural Steel Fabrication*, both having to do with preparing structural steel for erection as steel frames for buildings, railway and highway bridges and other types of structures framed of steel.

STRUCTURAL STEEL DETAILING

The courses in Steel Detailing and Steel Fabrication were established by the department to help partially solve the needs of Industry, in preparing the student to take his place in the structural drafting room as a detailer. In any large industrial city, such as New York, the need for well-educated individuals in the detailing field is acute. The training of detailers in the past has been lax because detailing is considered to be on the sub-professional level even though the detailer must have a knowledge of algebra, geometry, trigonometry, structural steel design and other allied subjects, as well as being a good draftsman.

The subject course of Structural Steel Detailing enables the student to use the steel construction manual and mathematical tables to detail beams, columns, trusses and girders. The course content is broken into five units of theory and six plates of detail drawings based upon practical steel design blueprints supplied by the instructor. The five Units of Theory are as follows:

I. Introduction to the Field of Structural Steel Detailing—General Information:
   - A. Step-by-step experiences of a structural steel detailer
   - B. Essential requirements for shop detail drawings, including drafting conventions and accepted practices
   - C. Class practice in use of tables in *Steel Construction Manual* with particular reference to contours of commonly used steel shapes

II. Beams Framed with Standard Connections:
   - A. General discussion and references

B. Copes, blocks and cuts
C. Various methods of showing and calling for standard beam connection angles
D. Methods of dimensioning
E. Steps in detailing with references
F. How to order length of beam

III. Beams with Seated Connections:
A. Beam seats without stiffeners
1. Advantages and disadvantages
2. Limitations
3. Bearing on seat
4. Choosing thickness
B. Beam seats with stiffeners
1. How to design members
2. How to choose standard in "Steel Construction Manual"
C. Making seated connections to flange and web of columns

IV. Columns:
A. Function of columns
B. Reading floor plans
C. Reading column schedules
D. Anchor bolt details
E. Erection clearances
F. Fabrication Clearance
G. Column Splices, Filler Plates and Butt Plates
H. Views and Dimensions
I. Bill of Materials

V. Skewed and Bevel Beams
A. Computations Necessary—Use of Mathematical Tables
B. Details and Layouts

The 6 drawing plates are worked in conjunction with the theory and are as follows:

A. Orthographic projection and lettering
B. Standard connections
C. Beams for seated connections
D. Seated connections
E. Columns
F. Skewed and bevel beams

The learning of Structural Steel Detailing is only partially completed by the student completing the course outlined above. This course will give him the theory and drafting skills required by Industry. However, it is sound practice to expose an individual to the fabricating end of detailing so that he can see and handle the steel, punch holes, grind, cut, weld, rivet and assemble. In his previous semesters the student, "through the design portions of the curriculum," had built up a background enabling him to visualize and handle the computing part of the theory and through the course in Structural Calculations he can use the Logarithmic and Trigonometrical functions, so vital in a Steel Detailer's daily routine. The foregoing, combined with a course in Structural Steel Fabrication, enables the graduate to find a place in industry as a well prepared beginner in theStructural Steel Detailing Industry.

STRUCTURAL STEEL FABRICATION

Structural Steel Fabrication may be defined as the cutting, punching and drilling of steel sections, in accordance with the exacting dimensions of detail drawing, so that they can be bolted, riveted or welded into structural units and subsequently erected into sturdy steel structures. It is not sufficient that a designer or detailer know the paper work alone; he must be thoroughly familiar with all the shop operations employed in the preparation of structural steel for assembly. He must know the practical side, and it is from the practical standpoint that the steel fabrication laboratory is presented. This course acquaints the student with standard shop practices and machine capacities. It helps him to make his details and designs with the shopman's point of view in mind. Only by knowing the shop problems can the designer or detailer facilitate and speed the process of fabrication.

By fabricating the structural units of portions of a structure the student is given ample opportunity in the steel fabrication laboratory to practice punching, drilling, template making, steel layout, riveting, welding and other fabrication shop methods.

Since the strength of any important structure rests in its steel framework, knowing the many aspects of the manufacture, fabrication and erection of structural steel will materially aid the student in becoming a competent technician in the construction field.

The Structural Steel Fabrication course is given both in theory and laboratory. At the student's first meeting in the laboratory, he is given the "Laboratory Procedure and Safety Regulations" that outlines his duties, and a complete set of safety regulations. He is warned that any violations of the safety rules will result in severe disciplinary action.

The safety rules include the wearing of gloves, goggles, footwear and welding mask or shield. They also include full instructions and safe operation of the punching machine, grinding machine, oxygen and acetylene cylinders, pressure regulators for cutting, oxygen and acetylene hose, cutting blowpipe, welding, cutting and lifting.

A breakdown of the course content of Structural Steel Fabrication is as follows: (the theory listed first and the laboratory following):

A. Steel Fabrication—Methods of Cutting Steel
1. Scope of Steel Fabrication
2. Fabrication Operations
3. Steel Cutting
4. Oxy-acetylene Flame Cutting
5. Apparatus
6. Operation

Laboratory: Safe shop practices and safe operation of equipment.

B. Oxy-acetylene Flame Applications
1. Welding and Cutting Steel
2. Review of Safe Operating Practices

Laboratory: Practice in cutting steel, brazing

C. Sources of Steel Supply
1. Stock Steel
2. Warehouse Steel
3. Mill Order Steel
4. Raw Materials

Laboratory: Assignment of laboratory projects

D. Steel Making
1. Manufacturing Procedure
2. Steel Manufacture Review

Laboratory: Practice in steel layout

E. Layout, Punching and Drilling
   1. Drafting
   2. Templates
   3. Layout Crews
   4. Punching Methods
   5. Drilling Methods
   6. Rules for Punching and Drilling

   Laboratory: Report No. 1—Template Making

F. Riveting
   1. Fitting-up Operation
   2. Reaming Procedures
   3. Riveting Machines
   4. Shop Riveting
   5. Field Riveting
   6. Shop Operations Review

   Laboratory: Practice in Fitting, Reaming and Riveting

G. Riveting vs. Welding
   1. Advantages of Riveting
   2. Disadvantages of Riveting
   3. Welding in an "all-riveting" shop
   4. Advantages of Welding
   5. Disadvantages of Welding
   6. Types of Welding

   Laboratory: Introduction to Shielded Arc Welding

H. Arc-Welded Structures
   1. Design of Arc-Welded Structures
   2. Riveting vs. Welding Review

   Laboratory: Practice in Shielded Arc Welding

I. Shielded Arc Welding
   1. Welding Machines
   2. Electrodes
   3. Arc-Welding Procedures
   4. Stress Calculations

   Laboratory: Practice in Welded Joints

J. Stress Calculations for Welds
   1. Types—Fillet, Butt, Plug
   2. Stress Calculations Review

   Laboratory: Report No. 2—Fabrication of Structural Portions of a Structure

K. Secondary Operations
   1. Milling
   2. Straightening and Bending
   3. Plate Rolling and Forming
   4. Machine Shop
   5. Blacksmithing
   6. Empires of Steel

   Laboratory: Practice in Weld Inspection

L. Oxy-acetylene Welding
   1. Fusion
   2. Bronze
   3. Brazing
   4. Secondary Operations Review

   Laboratory: Practice in Fusion and Bronze Welding

M. Finishing
   1. Completing Units
   2. Cleaning and Painting
   3. Inspection
   4. Shipping

   Laboratory: Practice in Inspection of Structural Units

N. Erection
   1. Columns
   2. Beams
   3. Trusses
   4. Building for the Nations

   Laboratory: Complete Erection of Model Mill Building

O. Final Review and Examination in Steel Fabrication
   Final Examination on Steel Fabrication Operations

   Laboratory: Final Report on Structural Lab Fabrication Operations

It should be noted from the course content that, though the student is exposed to welding in the lab, he is not given enough welding to make him a welder, but is given a good general background as to what goes into a steel skeleton, its make up and fabrication. We, in the Construction Technology Department, as well as in the entire College, are firm believers that learning can be faster and better accomplished if theory can be coupled with live lab work as actually done in industry.

The Steel Fabrication Laboratory is patterned after a professional steel fabrication shop. To facilitate the learning procedure, the laboratory is run entirely under student jurisdiction. The instructor gives a job to the student superintendent who, in turn, distributes the work to the foreman of the various shop groups. The super has an assistant and they make routing slips, patterns, templates, erection and shipping procedures. At present, the lab is equipped with power and hand punches, shears, riveting equipment, arc welders, oxy-acetylene equipment and small hand tools. There are three electric arc welding units and three oxy-acetylene outfits, complete with gages and attachments to operate six guns simultaneously.

The instructor in charge of the lab has a New York City welding and burning license and is highly skilled in the use of all the equipment.

CONCLUSION

The best way to be unhappy is to manufacture and place on the market a product that you like and your wife likes, which is unsalable. Educators, fortunately, do not manufacture but do place on the market products of their labors in the way of graduates. The graduate with a well-rounded background will have no trouble in finding his proper niche and making good in his chosen field, whereas one who received his education in a lax or haphazard manner will experience great difficulties.

The Construction Technology Department of the College educated its students to take their places in industry as technicians on a subprofessional level with a knowledge of industry's needs as of today and tomorrow. With that in mind frequent meetings with the Advisory Committee of the Department, together with visits to Industry, keep the curriculum and its subject content up to the minute. In the eight years of our existence, at least fifteen major revisions to the curriculum were made in accordance with the needs of industry.

About 95% of the students are placed on jobs in the construction industry upon graduation. The job titles include Assistant Field Engineers, Draftsmen, Concrete Detailers, Assistant Surveyors, Junior Architectural Draftsmen, Structural Estimators, Take-off Men, Engineering Draftsmen, Junior Civil Engineers, Structural Steel Detailers, etc. The average starting salary for the class of February 1954 was $60 per week. The

Structural Steel Detailing Industry employed a large number of the students. A large number of the firms have previously employed our students and keep coming back for more; for example, over a two-year period the Precise Drafting Co. of New York has employed ten of our students. At present they are working on a very complicated detailing job (a 25-story office building at 300 Park Ave., New York City) where rivets and welding both are used in the steel frame erection.

It is the intent of the Department to make a comprehensive study of Welding in the Construction Industry and try to further the education of its students by including more technical data on welding in its curriculum, as steel erection on a large alteration job such as 300 Park Ave. would be impossible without welding. More and more engineers are now calling for welded connections in their designs and we must be ready to fill that need when it occurs.

References used in the Steel and Fabrication Courses

1. *Structural Shop Drafting*, Vol. 1 and 2, American Institute of Steel Construction.
2. *Procedure Handbook of Arch Welding Design and Practice*, The Lincoln Electric Co.
3. *Manual of Design for Arc Welded Steel Structures*, by La Motte Grover, Air Reduction.
4. "Standard Specifications for Welded Highway and Railway Bridges Design, Construction and Repair," AMERICAN WELDING SOCIETY.
5. "Precautions and Safe Practices in Welding and Cutting with Oxy-Acetylene Equipment," Linde Air Products Co.
6. The Practical Design of Welded Steel Structures by H. Malcolm Priest—American Welding Society.

Adhesive Bonding Complements Soldering and Brazing

Basic materials used in adhesives, their characteristics and comparison with other joining methods

by H. H. Simons

THE engineer is constantly searching for new materials to satisfy the critical demand for modern instrument, tool and structural design. He is often prevented from using the ideal material because joining difficulties arise. The nature of the materials to be joined, the limitations set by heat, corrosion resistance, conductivity and other factors associated with soldering and brazing often make this joining method unsatisfactory, inadequate or impossible.

Adhesive bonding, when used wisely, can help the engineer solve many of these problems. Together with soldering and brazing, the engineer has an extremely versatile kit of tools for almost all joining problems.

It is the purpose of this paper to help the engineer in his choice by: (1) Outlining the kinds of basic materials used in adhesives and listing their characteristics. (2) Discussing the principles of adhesive bonding. (3) Comparing the advantages and disadvantages with respect to other joining methods.

Definition. Adhesive bonding may be defined as the joining of two materials by the use of a basically organic material as the bonding agent.

H. H. Simons is with the Eutectic Welding Alloys Corp., Flushing, N. Y.

Presented at the AWS National Spring Meeting held in Buffalo, N. Y., May 4–7, 1954.

TYPES OF ADHESIVES

The organic materials from which almost all adhesives are compounded fall into four groups. Three of the four are synthetic, the fourth a natural protein group. They are the Synthetic Thermoplastic, Synthetic Thermosetting, Rubber Base and Protein.

Adhesives are further classified by a bonding classification based on manner of use, and determined by the physical form and chemical properties of the adhesive. The bonding classifications are:

Solvent Release. The adhesives in this class are those dissolved or dispersed in a volatile solvent whose only function is to put the adhesive in a convenient application form. Release of solvent is necessary to prepare the joint. Release of solvent may be by air drying or with use of heat.

Fusion. In this class the adhesive is used in solid form as a powder, film or rod. Heat is required to produce the bond. The adhesive is either preplaced into the joint area or caused to flow into the joint while molten.

Cured. The adhesives in this class complete the bond through a chemical or polymerization reaction. Bonds are made at room temperature or with heat. Curing time will vary from 24 hr at room temperature to minutes at elevated temperatures.

These adhesives are available in 100% liquid resin

form, solvent, paste and solid. When obtained in solvent form, the solvent may enter into the reaction. When the solvent does not enter into the reaction, a solvent release procedure must be followed in addition to the curing schedule.

Vulcanization. This bonding method is confined exclusively to the rubber base adhesives, and may be considered as a special case of the cured type of bonding. Rubber base adhesives are obtained in solvent or solid form.

CHARACTERISTICS

A general description of the chemical types of materials within each group, the characteristics and best use of the types in the group and the bonding class is given below. Further data on the specific properties of the formulas falling into each chemical type, as well as sources for commercial products based on the various types, can be found in the *Modern Plastics Encyclopedia* and *Engineer's Handbook.**

Thermoplastic Adhesives

Chemical Types. (*a*) Cellulose Derivatives; (*b*) Acrylic esters; (*c*) Vinyl Resins; (*d*) Styrene Resins; (*e*) Alkyd Resins; and (*f*) Polyamide Resins.

Characteristics. The bonds prepared with adhesives in this group are all thermoplastic in nature. As such they will soften and be weakened by heat. The temperature at which they will lose strength will, of course, depend upon the softening point of the material.

Fungus resistance of this group is excellent. Resistance to heat, cold, water and solvents is variable.

The materials in this group find their greatest use for nonmetallic bonds, particularly paper, textiles and wood with the exception of several of the vinyl resins and the polyamide the bonds on metals are poor.

Bonding Class. All the adhesives in this group are in either the solvent release or fusion class.

Thermosetting Adhesives

Chemical Types. (*a*) Phenol Resins; (*b*) Resorcinol Resins; (*c*) Furane Resins; (*d*) Amino Resins; (*e*) Polyester Resins; (*f*) Silicone Resins; and (*g*) Epoxy Resins.

Characteristics. The bonds made with adhesives in this group are thermosetting. Properly prepared they will not soften with heat. The bonds will therefore be stronger over a wider temperature range than the thermoplastic adhesives.

The resistance to heat, cold, water and solvents is uniformly high and superior to the thermoplastic adhesives. This group is more versatile for use on nonmetals than the thermoplastic. In addition, a larger number give high-strength bonds with metals. The types most suitable for metals are the Epoxies, Silicones, Phenolic polyamide and Phenolic acetal compounds.

Bonding Class. The adhesives in this group are in the cured class.

Rubber-Base Adhesives

Kinds. (*a*) Natural Rubber; (*b*) Neoprene Rubber; (*c*) Reclaimed Rubber; (*d*) Butyl Rubber; (*e*) Thiokol; (*f*) Cyclized Rubber; (*g*) Chlorinated Rubber; (*h*) Butadiene-Acrylonitrile; and (*i*) Silicone Rubber.

* *Modern Plastics Encyclopedia* and *Engineer's Handbook*, Plastics Catalogue Corp., New York, N. Y., 676 (1953).

Table 1—Adhesives Suitable for Metal-to-Metal or Metal-to-Other-Materials Bonding

Good or Excellent Under Suitable Specifications, Conditions and Techniques

Adhesive group	*Chemical type*	*No.*	*Materials*	*Bonding class**	*Suitability*						*Resistance rating†*			
					Wood	*Metals*	*Rubber*	*Glass*	*Ceramic*	*Water*	*Solvent*	*Heat*	*Cold*	*Fungi*
Synthetic thermoplastic adhesive	Vinyl	1	Vinyl acetate or vinyl alcohol acetate	SR, F	E	E	F	G	G	M	M	M	M	E
		2	Vinyl chloride	SR, F	M	G	G	G	G	G	M	F	M	E
		3	Vinylidene chloride copolymers	SR, F	M	G	M	G	G	E	G	F	G	E
		4	Vinyl chloride acetate copolymer	SR, F	G	G	M	G	G	E	G	G	G	E
		5	Vinyl butyral	SR, F	E	E	G	E	E	M	M	M	M	E
Synthetic thermosetting resin adhesives		6	Miscellaneous—Polyamide	SR, F	E	E		G	G	E	G	M	G	E
	Phenol	7	Phenolic polyamide	F, H	E	E	P	P	F	P	F	M	E	E
	Special	8	Silicone	H	G	G	E	G	G	E	G	E	E	E
		9	Epoxy	R	G	E	E	E	E	E	E	G	G	E
				M	G	E	E	E	E	E	E	G	E	E
Rubber base adhesives		10	Neoprene rubber	SR	E	E	E	E	E	E	G	G	G	E
				V	E	G	E	P	F	E	G	E	G	E
		11	Butadiene-acrylonitrile	SR, F	G	E	G	G	M	G	E	G	G	E
				V	G	E	G	G	M	G	E	G	M	E
		12	Butadiene styrene rubber	SR	G	G	G	M	F	G	F	M	M	E
		13	Thiokol	V	M	G	E	G	M	M	M	G	G	E

* SR, Solvent release; F, fusion; R, room-temperature cure; M, medium-temperature cure; H, high-temperature cure; and Vulcanization.

† Ratings: E, excellent; G, good; M, medium; F, fair; and P, poor.

Characteristics. The bonds in this group can be either thermoplastic or thermosetting. The strength at elevated temperatures will therefore fall between the thermoplastic adhesives and the thermosetting adhesives.

Solvent, heat, cold and water resistance is also intermediate between the thermoplastic and thermosetting adhesives.

Bonding is good with all nonmetallics. The best types for metal bonding are the butadiene-acrylonitrile, Thiokol and silicone rubbers.

Protein

Kinds. (*a*) Casein; (*b*) Animal Glue; (*c*) Zein; and (*d*) Soybean Glue.

Characteristics. The adhesives in this group are more usually classed as glues. Their use is limited to special applications. They are all water soluble. This group is seldom used for joining metals.

Since most of the difficult joining problems arise in the desire to join metal to nonmetal, and metals to themselves, a chart, shown in Table 1, has been prepared comparing the properties of the best adhesives for use for joining metals.

PRINCIPLES

An organic bond may be considered as two surfaces joined by an organic film. The chemical and physical properties of the joint will depend upon the chemistry of this film. The strength of the joint will depend, additionally, upon the nature of the bonded surface, upon the manner in which the joint is made and upon joint design.

FACTORS AFFECTING BOND STRENGTH

Chemical

The strength of the film is determined by the cohesive forces of the components of the film. These are chemical and molecular in nature, and are properties of the material composing the film. The maximum cohesive strength can be obtained with any given material when the molecular size, shape, orientation and distribution is properly controlled. This is primarily the manufacturer's problem. It is important that the engineer understands that the adhesive as received is compounded for this maximum, and that any changes he may make or any deviation from procedure may result in decreased strength. The strength of the film for the adherand surface is related to the specific cohesion of the film material for the surface material. The dominant influence seems to be the chemical similarity of the two materials, similarity in respect to polarity. Unless both are similar in polarity a strong bond cannot be made. Metals, although not polar, are easily polarizable. As a consequence, the adhesive materials containing the polar hydroxyl, carbonyl, amino and chloro group make the best bonds with metals.

Physical

The strongest bond will be obtained when the film itself and the film to adherand surface form a continuous, unbroken system. Any entrapment of foreign matter, solvent residue or gases will tend to lower the cohesive strength of the film, decrease the effective surface area of the adherand, and will result in a lower bond of strength.

For the adherand surface cleanliness is the primary requisite. The surface must be free of grease and dirt. Oxide films on metals, if the oxide is not strongly adherent, should be removed. When porous surfaces are bonded, it is usually best to fill the pores, preferably with a material similar to the adhesive.

For the adhesive the bonding technique and joint design used are the influencing factors. In the solvent release class of material the solvent can be a cause for discontinuous films. Thin films and small gap clearance minimize the danger of solvent entrapment and result in stronger bonds. Use of pressure will attain the same result.

In the fusion and cured classes of adhesives the bond strength is almost independent of the film and gap thickness. Here the rate and manner of cure, and the completeness with which the adhesive wets the surface of the adherand are the controlling factors.

Joint Design

One of the major failings of organic adhesives is the poor peel strength of the bond. Joints are therefore designed to eliminate or minimize peel stresses. The lap, inset, butt strap and socket joint are the types of joints giving least peel stresses and are universally used. Overlaps are made so that ratio of thickness of section to length of overlap is 5:15.

PRACTICAL CONSIDERATIONS FOR ADHESIVE BONDING

The choice between any one of several adhesives that may solve the problem on hand should be determined by how closely the adhesive fits the requirements for an ideal adhesive.

The ideal adhesive:

1. Would cure to a maximum strength in a minimum time, preferably at room temperature. (The term "cure" is used here and in the following sections to mean the completion of the bond whether it be by solvent release, cure or fusion method.)
2. Would have no shrinkage during or after cure.
3. Would have elastic properties similar to those of the adherand material. If the properties differ appreciably, the adhesive would be flexible enough to accommodate differential deformation when the parts are under stress.

4. Would not give off any volatile reaction products during or after cure.

5. Would maintain its properties over temperature ranges between −65 and 400° F.

6. The adhesive when cured will be able to resist chemical attack and maintain its physical properties for long periods of time.

7. Would have high shear and peel strength.

8. Should be available in a form easy to apply.

9. The bonding method should be such that it can be adapted to available equipment and methods.

Unfortunately, no such ideal adhesive exists. Practically, an adhesive that is 100% resin, and in liquid form, will meet the above requirement the best.

COMPARISONS TO OTHER JOINING METHODS

For joining nonmetals adhesive bonding is the only practical method available other than mechanical joining. Compared to the latter the adhesive bond is more uniform, neater, makes liquid and airtight joints and resists fatigue and buckling stresses better.

For joining metal to nonmetal it again offers the only practical method.

For joining metals it offers the advantages of less weight per bond. The corrosion resistance toward acid and bases is superior to soldering and brazing. Because joints can be made at room temperature and at temperatures lower than those required by soldering and brazing, it permits joining of metals that are affected by heat. The bond has high resistivity.

On the other hand, compared to soldering and brazing the limitations in design due to poor peel strength, the requirements for a different adhesive for each specific application, the poor peel strength and limited shear strength and the presence of volatiles in working are some of the disadvantages.

The advantages and shortcoming of adhesives have been presented in the preceding chapters.

The design or production man who is faced with a problem that welding processes seem unable to solve adequately becomes interested in adhesives. Table 2 compares some of the properties of adhesive bonding, soldering and brazing. All three processes are related in one sense—that they use lower ranges of temperatures and it is well, therefore, to explore all three. Table 2 shows the properties of each process. It is well to note that the technique and materials used today for both brazing and soldering have advanced considerably in the last decade.

Table 2—Comparison of Some Important Properties of Adhesive Bonding, Soldering and Brazing

Property	*Adhesive bonding*	*Soldering*	*Brazing*
Bonding temperature, °	0–400	200–730	From 800 to melting point of base metal
Shear strength, psi	1000–3000	3000–8000	From approximately 20,000 and up
Corrosion resistance	Excellent	Fair	Good
Bondability:			
Metal to nonmetal	Good	Not used	Not used
Light metals	Good	Good	Good
Copper and Alloys	Fair	Excellent	Excellent
Ferrous metals	Fair	Excellent	Excellent

Light Metals

For extremely light gages of aluminum, adhesive bonding has often provided excellent solutions. Where design does not permit long lap joints, there are now new soldering materials, such as solder filled with special flux suitable for aluminum, that has given us excellent results. Where higher tensile strength is desirable, low-melting aluminum brazing filler metal with specially designed fluxes is also successfully used.

Copper and Copper Alloys

For extremely light gage of copper and heat-treated alloys such as beryllium copper, etc., adhesives will give satisfactory results even though the strength values will not be as high as on aluminum. For greater strength there are specially formulated solder type alloys for copper and brass with fluxes in the core or the more recently developed mixture of flux with solder in paste form which should be used when higher strength is needed. Where corrosion resistance and still greater strength values are desired, silver alloys are often recommended. Among these, we have had excellent results with powdered silver alloys mixed with the adequate flux and used in paste form, particularly where higher heat resistance and conductivity is required.

On Ferrous Metals

Adhesives are used in many instances where extremely light gages have to be bonded particularly on alloy steel or stainless steel although the strength values are in the lower part of the range indicated in Table 2.

More practical, in many instances, has been the use of soft solders particularly in paste form (solder and flux combined). Also various soft solders developed for higher strength (cadmium base) have also given excellent results. Where higher strength and higher heat resistance are needed, specially developed silver alloys are now available in addition to the silver alloy of the B A G classification. One of the most successful for stainless steel particularly has been a new alloy of copper, silver and nickel. Quite often light gages, when high strength is required, have been joined with the above alloys when the design did not permit a lap joint with BCuZn7.

Automatic Horizontal and Vertical Welding of Field Erected Structures

Newly developed flux-supporting devices permit automatic submerged arc welding of horizontal and vertical joints in field-erected structures

by Amel R. Meyer

Abstract

The basic principles for the automatic submerged arc welding of horizontal and vertical joints in vertically positioned plates are described. Both welding processes are based on the use of newly developed flux supporting devices. These devices are designed to maintain a stable flux bed at the welding site and to support the flux cover and the molten weld deposit throughout the solidification cycle.

The construction and operation of a horizontal and a vertical welding unit, designed especially for use on field-erected storage tanks, is discussed.

Horizontal and vertical submerged-arc-welded joints regularly meet the standards for soundness and strength properties expected of those made in the flat position. Welding procedures and recommended quality controls are reviewed. Typical welded joints obtained with the described procedures are illustrated, together with examples of common weld defects which result from improper operation or inadequate control.

The application of automatic welding methods to large storage tanks necessitated a complete re-evaluation of field erected procedures. Welding times were shortened by as much as five times, but plate preparation costs and erection time was increased due to the greater demand for uniformity of joint fit-up. The overall erection time, however, is generally reduced.

Even if no immediate cost advantage were to result, the increased weld quality and uniformity obtainable with automatic welding methods is believed to be ample justification for continued development and use on important structures.

INTRODUCTION

THE submerged-arc welding process was originally developed and is now used widely on structures which can be positioned for flat down-hand welding. Recently developed procedures, adapting the submerged arc process for welding a horizontal joint in vertically positioned plates, are now available for use on field erected structures. This process is now used extensively for welding the girth seams of field-erected oil storage tanks.

Companion equipment, adapting the submerged arc process to vertical welding, has been developed to the state that vertically welded butt joints comparable to those made in the flat and horizontal positions can be expected. The development and exploitation of the vertical submerged-arc welding process will enable the field erecter to produce a welded product comparable in quality and uniformity obtainable now in shop-built structures.

This paper is intended to describe horizontal and vertical submerged-arc welding equipment and procedures designed specifically for use on large storage tanks.

WELDING PROCESS

Submerged arc welding is characterized by the high welding currents used, with consequent high burn-off rate of electrode and deep penetration into the base metal. For welding in the flat position, positive support of the molten weld metal and overlaying flux is afforded by the surrounding base metal and possibly an underlying backing member. In the flat position, therefore, a relatively large size of molten weld pool and an extended solidification time can be tolerated and is even beneficial in allowing ample time to reach equilibrium between weld metal and the overlaying flux layer.

Horizontal Welding

The foremost requirement for submerged arc welding of a horizontal joint in a vertical surface is a stable flux bed. While only a small part of the direct support necessary to hold the molten weld deposit in the horizontal joint is provided by this flux bed, it is the principal supporting medium for the very fluid overlaying molten flux layer. This molten flux layer is the weld cleansing and surface wetting medium, promoting uniform fusion of the weld nugget in the base metal, and in addition, it protects the molten metal from oxidation during the solidification period. Any accidental settling or falling away of the granular flux bed has an immediate effect in disrupting the continuity of the molten flux layer, particularly at the upper edge of the

Amel R. Meyer is Chief of Welding Research, Graver Tank & Mfg. Co., Inc., East Chicago, Ind.

Presented at the AWS National Spring Meeting held in Buffalo, N. Y., May 4-7, 1954.

weld bead. The attendant lack of fusion at that upper edge permits the weld bead to sag or roll out of the joint. Any longitudinal movement of the flux cover, relative to the plate surface has a similar disrupting effect upon the molten flux layer and the molten weld deposit.

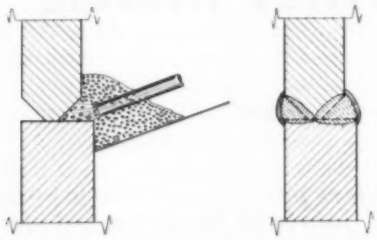


Fig. 1 Submerged arc weld—horizontal joint

With a stable flux cover, the arc is positioned and directed so as to produce a flat or slightly cup-shaped fusion line on the upward facing square edge of the weld joint, Fig. 1. The electrode is directed downward toward the joint at an angle of approximately 18 to 22 deg below the horizontal in a plane perpendicular to the plate surface. The electrode is then positioned so that the centerline of the projected arc stream will contact the lower flat face of the joint at mid-depth of the welded deposit. The essentially flat shelf thereby maintained under the molten pool is an important factor in the support of the weld deposit particularly for relatively heavy single pass welds and for the root beads in multipass welds.

Like most other horizontal welding procedures, horizontal submerged arc welding calls for a deposit consisting of a series of relatively narrow stringer beads. High current density and low arc voltage carried on an electrode smaller in diameter than is generally used for flat welding results in a concentration of welding heat across a narrow bead surface, $2^1/_2$ to 4 times the wire diameter in width. Comparative welding conditions for a square butt joint (in $^1/_2$-in. thick plate) welded in the flat and horizontal positions, are shown in Table 1.

Since the welding conditions are essentially equal on both sides of a horizontal joint in a vertical surface it is convenient to weld both sides simultaneously. The opposing arcs are generally staggered to reduce the instantaneous heat level at the welding site. The amount of offset between the leading and trailing arc is not considered critical so long as adequate control of penetration and shape of the trailing weld bead can be maintained. Once selected, however, that arc offset is preferably held constant for any given set of welding conditions.

Table 1—Comparative Welding Conditions—Butt Welds in $^1/_2$-In.-Thick Plate

Position of joint	*Joint design*	*Electrode diameter, in.*	*Current density, amp/-in.²*	*Total heat input, joules/-in.*
Flat	Sq. butt	$^3/_{16}$ (both sides)	27,000	130,000
Horizontal	Sq. butt	$^1/_8$ (leading arc)	49,000	64,000
		$^3/_{32}$ (trailing arc)	67,000	
Vertical	60-deg double bevel	$^3/_{32}$ (twin arc) (both sides)	25,000	95,000

Vertical Welding

For the submerged arc welding of a vertical joint, a stable flux cover must be maintained in that portion immediately adjacent to the welding zone. In addition, a positive upward and inward (toward the plate surface) pressure must be applied to the welding zone. The inward pressure holds the deposited metal in position until it solidifies. It has been found to be impossible to positively support and shape one liquid body through an intervening liquid body. Consequently, an upward pressure was developed for continuously expelling essentially all of the molten flux as it accumulated, at a point just below the arc and before the start of solidification of the weld deposit.

The submerged-arc welding process, as adapted to vertical welding, might more closely be described as a "compressed-arc" method. A compressible glass fiber strip is flux loaded as it is continuously carried toward the welding zone, as illustrated in cross section, Fig. 2. As this strip is rolled onto the base plate over a pressure shoe or roller, the outer portions of the flux mound are urged inwardly and upwardly, pressing toward the arc zone.

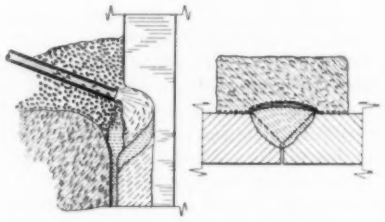


Fig. 2 Submered arc weld—vertical joint

The inward flux movement maintains a constant suporting pressure on an inner core of the flux mound, immediately adjacent to the joint, which remains stationary relative to the plate surface. As the flux in this inner core is melted by the welding heat, the major portion of it is continuously expelled and replaced by the inward moving granular flux. Final firm support of the deposited weld metal is effected by the partially compressed glass fiber strip acting through a very thin layer of fused and unfused flux.

The major part of the molten flux is continuously squeezed upwardly and laterally, off the weld deposit and away from the arc zone, and continuously and uniformly expelled through a low pressure zone created by vents at either side of the arc. These vents, triangular in shape, are formed by the lower edge of the flux nozzle, the base plate and the pressure strip. They

are naturally self-cleaning as the pressure strip moves under this opening and onto the base plate. Some small amount of granular flux flowing through each vent tends to accelerate the outward movement of the ejected molten flux and to insulate the main body of the pressure strip from the high-temperature materials. This granular flux is subsequently salvaged by a vacuum recovery system.

WELDING EQUIPMENT

Horizontal Welder

One successful horizontal submerged-arc welder design is shown in side elevation in Fig. 3. An identical welding head arrangement is mounted on the opposite, or back, side of the machine. This welder was designed specifically for use on large storage tanks where each successive shell ring is erected and welded in succession to the immediate lower ring as erection progresses. Standard equipment was incorporated in this design where available with a minimum modification commensurate with field operating requirements.

The horizontal welder illustrated is a combination of the following functional elements:

(*a*) A carriage adapted to travel at a uniform and controllable speed along the exposed free edge of a vertical plate.

(*b*) Welding head assembly, made up of a swinging frame with welding head, operating controls and flux support devices.

(*c*) Flux supply system.

(*d*) Operator's platforms.

(*e*) Accessory equipment.

The carriage consists of a central load-carrying beam and a light tubular frame structure extending downwardly, approximately $2^1/_2$ ft and straddling the vertical plate on which it rides. Flanged wheels at each end of the center beam, one of which is power driven, support and guide the carriage along the plate edge. Casters at the lower corners of the plate-straddling frame provide lateral stability to the carriage. Two vertically adjustable members, mounted on the center beam, straddle the vertical plate and support opposing welding-head assemblies at their lower ends. The light tubular structure over the top of the carriage supports a canvas weather cover.

The welding head assembly is pin connected at the lower end of each supporting member so as to be freely swingable in a plane perpendicular to that of the intervening plate, as shown in Fig. 4. The several components of this swinging welding head assembly are so located that their combined weight produces a turning moment about the connecting pin. This turning moment forces the end rollers of the flux-supporting device into positive contact with the vertical plate surface. Positive and uniform radial space relationship is thus automatically maintained, regardless of plate surface irregularities, between the welding head and the joint to be welded. In addition, the vertical orientation of the welding electrode, relative to the joint, is maintained regardless of ordinary transverse or radial movements of the carriage.

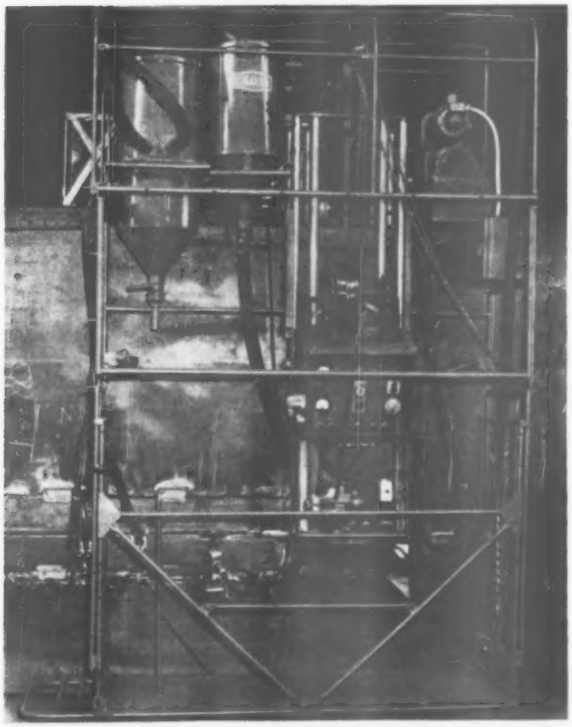


Fig. 3 Horizontal submerged arc welder in operating position

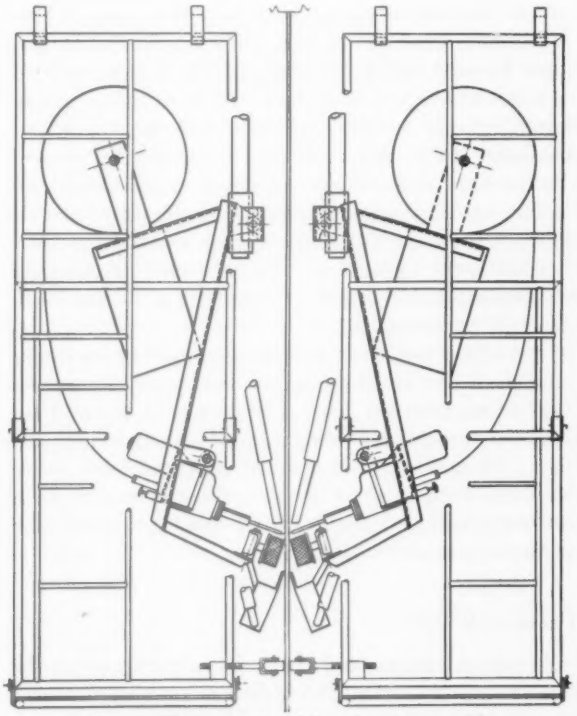


Fig. 4 Horizontal welding head assembly

Fig. 5 Horizontal submerged-arc flux supporting device

The construction of the horizontal flux-supporting device is illustrated in Fig. 5. The rubber-faced end rollers, bearing the eccentric weight of the welding head assembly, are friction driven on the surface of the shell plate as shown in Fig. 4. Successive portions of a flat, heat-resistant belt are rolled into position under the arc, at a rate controlled directly by the forward movement of the carriage, so as to provide a stationary flux-supporting shelf for the length of the upper belt run. Within design limits, springloaded rollers force the flux-carrying upper run of the belt into positive edge contact with the vertical plate surface regardless of plate-surface curvature or irregularities. An underlying supporting shelf prevents sagging of the upper belt run between the end rollers.

The flux supporting device, as illustrated, was designed to operate on a curved surface of 40 ft radius or greater. It has been operated successfully, with some increase in belt wear, on 60-ft diam (30-ft radius) tank shells. Alternate flux-supporting devices are available for use on tank shells as small as 20-ft diam, or less.

The flux recovery system, shown mounted in the upper forward end of the carriage, Fig. 3, is a standard vacuum recovery, recirculation system. The single unit effectively recovers approximately 10 lb per min maximum total flux from the two welding heads. Gravity-type flux recovery systems, with manual reloading of flux hoppers, have also been used successfully. Use of the automatic system results, however, in a uniformly cleaned and graded recovered material and permits the operator to concentrate on control of the welding operation.

Operator's platforms provide both safety and convenience in the use of automatic welding equipment on large storage tanks. Operator fatigue is reduced for long uninterrupted welding runs of as much as 2 and 3 hr. In addition, the operator can direct his entire attention to the control of the welding operation without worrying about maintaining a footing on temporary or inadequate scaffolding.

Vertical Welder

A vertical submerged-arc welder, mounted on the second ring of a 100-ft diam storage tank, is shown in Fig. 6. Canvas weather covers were temporarily removed to reveal structural details. An identical welding head arrangement is mounted on the opposite side of the machine.

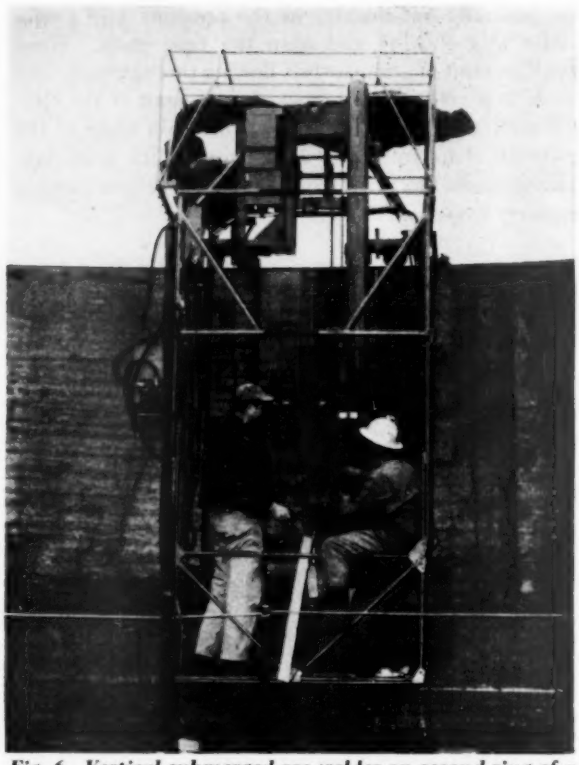


Fig. 6 Vertical submerged arc welder on second ring of a 100-ft diam tank shell ring

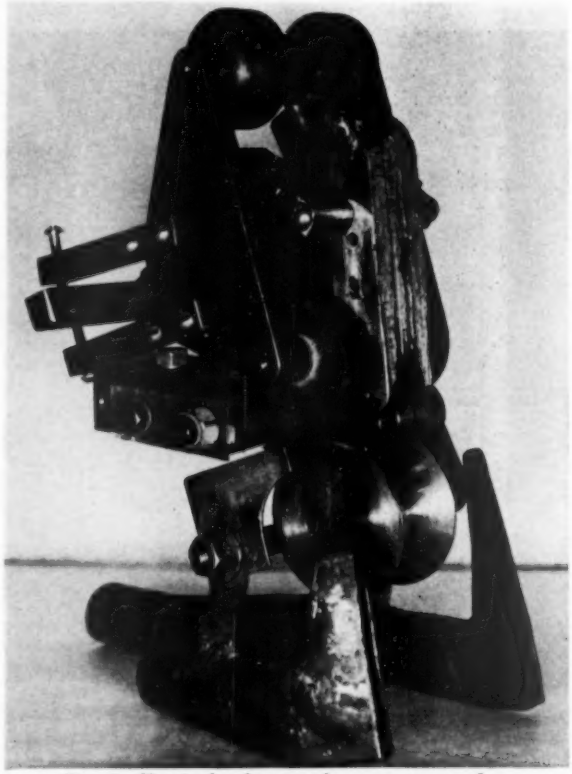


Fig. 7 Vertical submerged-arc pressure shoe

The carriage, riding the free edge of the vertical shell plates, may be power driven or manually propelled in moving to successive joints. Twin vertical columns in this design, rigidly mounted to the carriage, straddle the plate to guide the welding head assemblies along the vertical joint. The entire carriage can be tilted in the plane of the plate to accurately align the guide columns with the joint before welding. A free swinging welding head assembly, identical in principle to that of the horizontal welder, positively and uniformly positions the vertical welding shoe at the plate surface regardless of plate surface irregularities or minor radial misalignment between the guide column and plate surface.

The construction of the vertical pressure shoe, or weld supporting device, is illustrated in Fig. 7. A grooved pressure roller and the electrode nozzle are held in a predetermined space relationship to each other and to the plate surface. Successive portions of a compressible glass fiber strip, not shown, are carried under the electrode nozzle, over the pressure roller or shoe and onto the plate surface. A flux chute, bearing on the plate surface and partially surrounding the electrode nozzle maintains a continuous and uniform flux coverage at the welding site.

WELDING PROCEDURES

The quality of a welded joint is determined by the specific welding procedure used and the ability of the operator to consistently apply that procedure. Acceptable results cannot be expected, however, even with the best welding methods, if poor materials are used, or if improper or inadequate joint preparation precedes the welding operation. Tolerances governing edge preparation, fit-up and surface condition for automatic welding methods are generally more restrictive than is considered necessary or economical for manual welding procedure and close control of these variables is particularly important to the successful use of automatic welding methods for horizontal and vertical joints.

Horizontal Welding

Field experience has shown conclusively that all accumulated dirt, grease and rust must be removed from the surfaces of a horizontal joint to prevent weld porosity and to reduce undercutting. Black oxide films remaining from flame-cutting operations and normal amounts of mill scale generally do not adversely affect weld quality. Before erection, all plate edges at the horizontal joint are wire brushed to remove loose foreign particles, then lightly ground on the faying surfaces to remove deep-seated rust. In addition, all horizontal joints are flame descaled and dehydrated, then power brushed immediately ahead of the arc on each weld pass. After final fit-up, it is preferable to deposit at least the root passes immediately, to prevent re-entry of wind-borne or rain-washed foreign matter into the tightly butted portions of the joint.

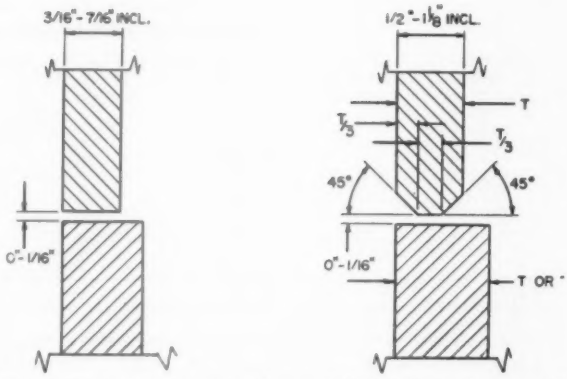


Fig. 8 Plate edge preparation and joint fit-up horizontal submerged arc welding

Plate edges prepared as shown in Fig. 8 for horizontal joints to be submerged arc welded, have been found to be the best adapted to the deposit of welds with acceptable uniformity and predictability. The plate edges may be prepared by shearing, flame cutting or planing, wherever applicable, without noticeable effect on weld quality, so long as plate dimension tolerances can be maintained with the method selected. Over-all dimensional tolerances considered adequate to permit the fit-up of both horizontal and vertical welding joints of desired uniformity are suggested, as follows:

Plate length	$\pm 1/8$ in.
Plate width	$\pm 1/32$ in.
Squareness (difference across diagonals)	$3/16$ in.
Lack of flatness across ends:	
Plate $3/16$ to $5/8$ in. thick, $1/8$ in. per foot, max	
Plate over $5/8$ to $1\,1/4$ in. thick, $1/16$-in. per foot, max	
Edge Bevel	$\pm 3°$

Root openings in horizontal joints which exceed $1/16$-in. width generally must be closed with a manual seal bead before welding with the automatic submerged arc process.

The deep-penetrating characteristic of the submerged arc process cannot be exploited in horizontal welding procedures, at least to the extent normal with flat welding, primarily because of the narrow width of bead which must be maintained to prevent overlap. A weld nugget with greater depth of penetration than it has width at the surface is subject to premature solidification at the narrow bead face with consequent slag entrapment and internal shrinkage cracks. Since a horizontal weld bead seldom exceeds $5/16$-in. average width, square butt, tight joints are generally not recommended for plates heavier than $1/2$-in. thick.

Welding conditions, developed to insure completely fused and consistently sound horizontal submerged-arc welded joints in tank quality steel plate, are suggested in Table 2. These procedures were developed using direct current with electrode positive. A high density d-c arc tends to be unstable in the first portion of a weld joint and when welding at high travel speeds. Arc instability, when encountered, is sometimes partially corrected by adjustment of the location of the ground connections or it may be necessary to reduce both arc

Table 2—Horizontal Submerged-Arc Welding Operating Data*

Plate thickness, in.†	No. of weld beads, each side	Electrode leading arc	Trailing arc diam, in.	Arc current, amp‡ Leading arc	Arc current, amp‡ Trailing arc	Arc voltage§ Leading arc	Arc voltage§ Trailing arc	Travel speed, ipm
1/4	1	3/32	3/32	425/475	325/375	27/30	25/28	40/45
3/8	1	3/32	3/32	475/525	375/425	27/30	26/29	30/35
1/2	1	1/8	3/32	500/600	400/450	27/30	26/29	28/33
5/8	1	1/8	3/32	600/650	425/475	28/31	26/29	25/30
	2	3/32	3/32	350/400	325/375	25/28	25/28	38/43
3/4	1	1/8	3/32	625/675	490/540	33/37	33/37	16/21
	2	1/8	3/32	480/530	400/450	29/32	29/32	28/33
	3	3/32	3/32	350/400	325/375	25/28	25/28	38/43

* Based on the use of Lincoln Type 760 flux and L.-C. rimmed steel filler wire using direct current with electrode positive.
† Thickness of the upper plate.
‡ Simultaneous welding both sides of joint, 5-in. offset between opposing arcs, with the leading arc on the offset side of the joint (Fig. 8).
§ Low arc voltage with high travel speed. High arc voltage with low travel speed.

current and travel speed for a short distance at the start of a joint. Welding speeds are generally limited to a maximum of 50 ipm although satisfactory welds have occasionally been made in 1/4-in. thick plate at welding speeds as high as 65 ipm.

Welded joints made following the described procedures, regularly meet and exceed the requirements for mechanical properties, ductility and soundness as specified in API 12–C, code for Welded Oil Storage Tanks. Representative sections of horizontal submerged arc welds, taken by trepan section from field welded joints, Fig. 9, illustrate typical bead contour, soundness of deposit, and penetration which can be expected with average welding practice.

Although two-thirds minimum penetration (one-third penetration from each side) is permitted under API 12-C code rules for horizontal joints welded by manual arc methods, it has been found necessary to set up procedures which will assure 100% fusion for all horizontal submerged arc welded joints. Complete fusion is necessary to insure the removal of any gas-producing foreign matter which may have been trapped in the tight butting root portion. It is even more important from the standpoint of structural safety to eliminate the crack-inducing sharp notch which might otherwise be present at the root of a partially fused, closed butt joint.

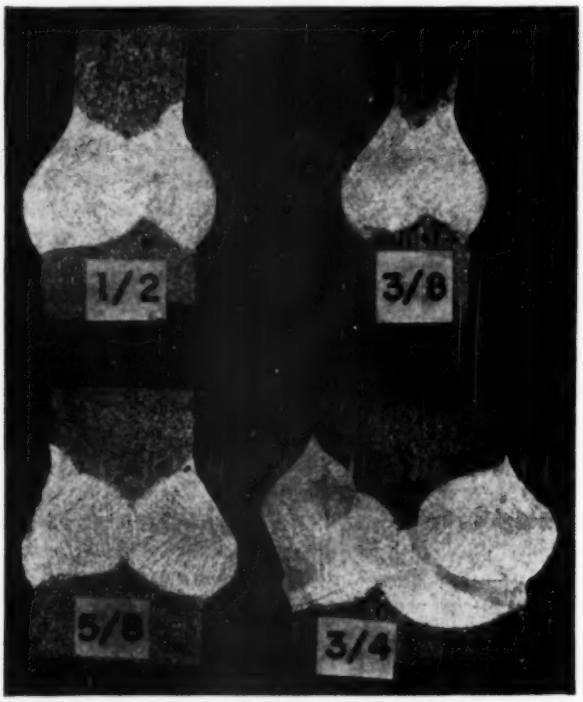


Fig. 9 Representative horizontal submerged-arc welded joints as found by trepan section inspection of field-erected tanks

Vertical Welding

Like other commonly used vertical welding procedures, vertical submerged arc welding calls for a weld deposit consisting of a number of shallow weld layers extending across the full width of the joint. A uniform distribution of the welding heat across the full width of the vertical weld layer is considered essential to insure adequate fusion at the outer edges which tend to be chilled by contact with the compressed granular flux cover. This wide heat distribution has best been obtained by the use of twin arcs placed transverse to the direction of welding, using a single d-c, or a single-phase a-c, welding circuit.

Plate edge preparation and fit-up tolerances for vertical submerged-arc-welded joints are suggested in Fig. 10. Although welding procedures may still be considered to be in the development stage, the welding conditions given in Table 3 closely reflect current prac-

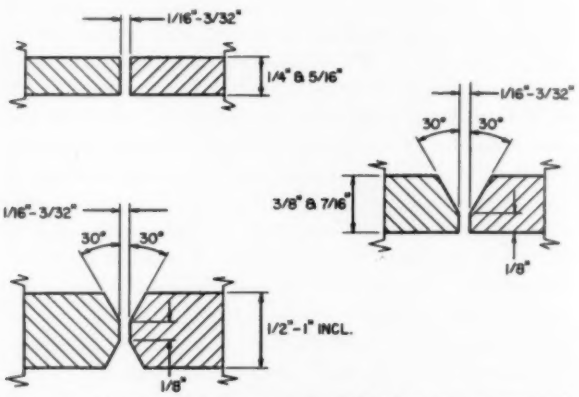


Fig. 10 Plate edge preparation and joint fit-up vertical submerged arc welding

Table 3—Vertical Submerged-Arc Welding Operating Data*

Plate thickness, in.	*No. of weld passes, each side*	*Arc current, amp* — *Leading arc*	*Trailing arc*	*Arc voltage*	*Travel speed, ipm*
1/4	1	300/325	350/375	28/32	15–17
3/8	1	300/325	375/400	28/32	13–15
1/2	1	325/350	400/425	38/32	12–14
5/8	1	350/375	400/425	28/32	12–14
	2	375/400	350/375	28/32	
3/4	1	400/425	400/425	28/32	10–12
	2	400/425	375/400	28/32	
1	1	400/425	400/425	28/32	10–12
	2	400/425	375/400	28/32	
	3	400/425	375/400	28/32	

* Based on the use of Linde No. 80, 20 x 200 flux and 3/32-in.-diam medium manganese filler wire, twin arc with zero spacing, with electrodes positive.

tice. The initial weld pass is deposited against a copper backing bar which prevents the loss of molten metal through the root opening. Subsequent passes, where required, are deposited simultaneously on each side of the joint with the arcs staggered 8 to 14 in.

Welded joints made in the laboratory and pilot field tests, following the described procedures, have regularly met the requirements for mechanical properties, ductility and soundness as specified in API 12-C, code for Welded Oil Storage Tanks. Representative sections of vertical submerged arc welds, taken from those test joints, are shown in Fig. 11.

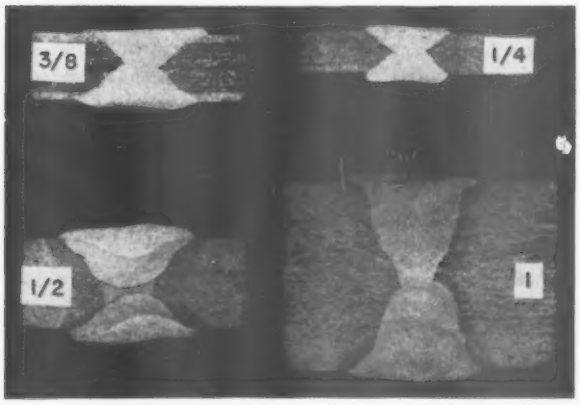


Fig. 11 Representative vertical submerged-arc welded joints taken from procedure qualification plates

In addition to the welding conditions normally specified for a welding procedure, variables peculiar to the vertical submerged arc process have an important influence upon the quality of the weld deposit obtained. As the granular flux is pressed against the surface of the plate, a compacted inner flux core of downwardly increasing density is formed along the joint. The length of this compressed core zone is directly related to the diameter of the pressure roller used. In turn, the total pressure which can be impressed on this inner core is dependent upon the degree of compressibility inherent in the pressure strip and upon the shape of the underlying pressure roller.

The vertical positioning of the electrode in the compressed flux core determines the amount of direct supporting pressure applied to the deposited weld metal. It also determines the amount of supporting granular flux available to displace the molten flux. Side restraint on the arc and weld deposit is determined by the width of the flux bed carried on the pressure strip. In practice, a 1 1/4-in. wide flux bed is maintained, which is just sufficient to completely enclose the arc, while offering a minimum resistance to the outward flow of molten flux as it is ejected from the welding zone.

WELD DEFECTS

All of the weld metal defects common to other fusion welding processes are also to be found in horizontal and vertical submerged arc welds; undercut, overlap, porosity, slag inclusion, weld misalignment or lack of fusion and cracking. Extensive field experience with the horizontal submerged-arc welding process has demonstrated that with proper adherence to established procedures, weld defects can be reduced to a level which is far below that obtained with manual welding methods. Laboratory and field tests of the vertical process has indicated that weld qualities comparable to those obtained regularly in horizontal welds can be expected. Welded joints are produced under normal field working conditions, which meet X-ray soundness standards equal to those expected of flat welds made under good shop conditions.

Undercut in horizontal welds is generally the result of low arc voltage, excessive travel speed or the combination of both. Arc instability also contributes to this condition, generally accompanying poor bead contour and slag inclusion. Fused slag clinging tightly to the upper edge of a horizontal weld bead is generally a certain indication, to the welding inspector, of undercut sufficient to demand repair. Undercut in vertical welds is generally accompanied by run back of the weld metal resulting from excessive heat input or arc instability and is therefore one of the less serious weld defect factors.

Overlap is one of the more serious defects encountered in vertical welds and will be found to be present to some extent in the cross sections shown in Fig. 11. Overlap is the direct result of excessive holding pressure on the plastic portion of the weld deposit and is being reduced with continued experience with the process. Overlap or roll-over in horizontal welds results with over-size weld deposits or malfunction of the flux support belt causing turbulence in the flux cover.

Porosity, extending to the weld surface as shown in Fig. 12A, will almost invariably result in a horizontal joint which has been improperly cleaned before final fit-up. Wind-blown or rain-washed foreign matter accumulated in a joint before welding has a similar reaction on the weld. The importance of careful cleaning before fit-up and immediate welding after fit-up cannot be overemphasized since corrective measures taken later can only be partially effective at best. Porosity is seldom encountered in vertical welds deposited at the currently slow welding speeds in the open type of joint. As the joint is closed up and welding speeds are increased, however, porosity begins to appear due to insufficient deoxidation of the quick-freezing weld deposit.

Slag inclusions in a horizontal weld generally occur with misalignment of the opposing weld beads or lack of proper fusion into the base metal, Fig. 12B. The beveled joint design, illustrated previously, is intended to reduce the possibility of both misalignment and lack of fusion but operator control is required to maintain stable arc conditions and proper positioning of the electrode at the joint.

Slag inclusions are generally located in the root of a vertical submerged arc weld and are the result of insufficient cleaning of the back side of the root pass. Back chipping is not considered necessary, however, except where heavy slag inclusions or lack of fusion is found in the back face of the root pass. Cleaning by wire brushing is generally sufficient to insure complete penetration and fusion by the trailing pass.

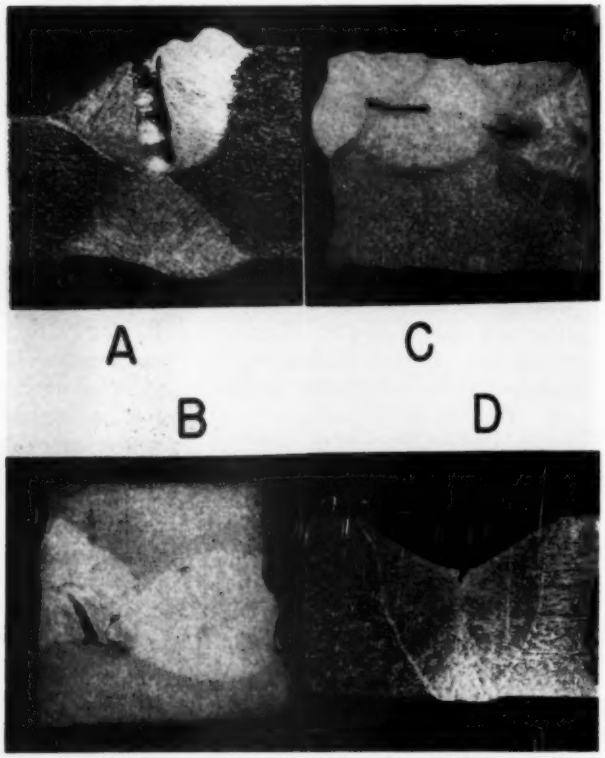


Fig. 12 Horizontal and vertical submerged-arc welding defects

Cracking, as such is surprisingly absent from both horizontal and vertical submerged arc welds deposited in tank quality steel plate. Pipe or shrinkage cavities, which are frequently mistaken for cracks, have been found, however, in both horizontal and vertical welds. This condition is particularly serious in horizontal welds since the cavity seldom extends to the surface of the weld, Fig. 12C, and therefore, may not be detected and corrected.

In early attempts to utilize the deep penetrating characteristics of the submerged-arc welding process, with horizontal welds, square butt or shallow beveled joints were welded in plates up to 1-in. thick. The joint shown welded in Fig. 12C was one of this type with a 20-deg single bevel groove, $^3/_8$-in. deep. The resulting weld nugget on the deep penetration side of that type of joint was frequently as much as two times as deep as it was wide at the surface. In order to penetrate to such depths while holding the width of the bead to a minimum it is now realized that the arc was actually forced to operate beneath the surface of the plate. A minimum of heat was released at the outer edge of the joint and as a result the nugget solidified inwardly from the surface practically guaranteeing an internal shrinkage cavity.

The joint preparation illustrated previously in Fig. 8, was designed to assure complete fusion without the requirement for deep penetration into the root of the joint. Care must still be exercised, however, in depositing the initial root passes to insure that sufficient heat is released at the surface of the bead to prevent premature solidification at that point.

A similar type of cracking has occasionally appeared on the surface of vertical weld deposits, Fig. 12D, but has seldom extended inward more than $^3/_{64}$ to $^1/_{16}$-in. These vertical weld cracks are usually found to be associated with concentrated heat input from a single electrode arc and the higher welding speeds. They have not been observed in twin-arc welds made with current suggested practice.

OPERATION METHODS AND ECONOMIES

The application of automatic welding methods to the welding of large storage tanks has necessitated a careful re-evaluation of field erection methods. Experience has indicated that the horizontal submerged arc welder with two operators, has a productive capacity equal to that of about eight manual welders using regular procedures, after allowance for machine handling and setup. The vertical welder is now capable of producing at about one-half the rate of the horizontal machine but this rate is being raised with increasing experience in its use.

An integrated setup for horizontal or vertical submerged arc welding in the field consists of the welder, welding current generators or equivalent rectifiers or transformers, interconnecting welding and power cables and a primary power source. The welding machines, which are the only items actually mounted on the tank

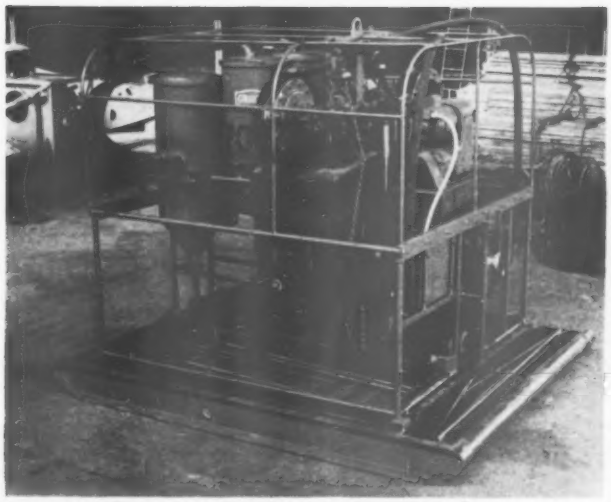


Fig. 13 Horizontal submerged arc welder, retracted for shipment

shell, have a dead weight of approximately 2400 lb. This is also the weight of the average size 1/4-in. thick tank shell plate, therefore, crane equipment capable of handling the normal size tank shell plate can be expected to safely handle these automatic welders to the full tank shell height.

Two systems of spotting the various elements are in present use. In one arrangement the welding generators are spotted in the center of the tank to be welded and connected to a primary power source (generator or line station). With 150 ft of welding and control cable, the welding units are then free to operate on shells up to 100 ft radius and 40 ft high. With this arrangement, equipment handling is minimized so long as work is confined to one tank. However, the weight of the interconnecting cables hanging inside the shell acts so as to pull the shell inward. This becomes a factor when operating on the uppermost and thinnest shell rings.

In a second arrangement, the welding generators and a portable power generator are assembled on a trailer. This rig is then spotted outside the tank near the shell. With the same 150 ft of interconnecting cable the welder can then be operated over a span of at least 100 ft each side of the generators. This permits the welding of each ring of the average size tank with just one shift of the rig. This arrangement is preferred on locations where more than one tank is being erected simultaneously. In addition, with all cables hanging outside the tank, the shell is more stable under the load of the machine.

The submerged arc welders come to the job site mounted on a skid, Fig. 13, and protected by a permanent weather cover. The retracted machine forms a package approximately 6 ft wide by 7 ft 9-in. high by 6 ft 6 in.-long. The welding heads and all other working parts are fully connected electrically and mechanically, as received, except for the operator's platforms. Two men can unpack the welder and set it up for operation in approximately one hour.

As each successive shell ring is completed the welder is lifted intact to the next ring as soon as at least one-half that ring has been erected and firmly clipped into place. When the last ring is completed, the machines are retracted, the inside operator's platform and connecting cables are removed, then a vertical lift of not more than 3 ft clears the machine of the tank shell.

CONCLUSIONS

Experience over the past several years has proved that the horizontal submerged-arc welding process is capable of producing welds of the highest quality with dependable consistency. Although experience with the vertical submerged-arc welding process is limited, present tests have indicated that it is capable of a development equal to that of the horizontal process.

These machines are making it possible to remove a little more of the human element from a class of work which always has been and still is subject to the vagaries of transient labor. A high degree of skill and experience is required to operate this equipment, and all operating personnel must be thoroughly trained and qualified on the process before being permitted to work in the field.

These machines are specialized, high-production items which are not adaptable to other uses than that for which they were designed. It is estimated that these machines must produce at full capacity for at least 200 hr per year before any savings can result from their use. Even if no immediate cost advantage were to result, however, the increased weld quality and uniformity obtainable with automatic welding methods is believed to be ample justification for their continued development and use on important structures.

ACKNOWLEDGMENTS

The author wishes to thank the management of the Graver Tank and Mfg. Co., Inc., for their permission to present this material and to thank those many members of the Research & Development and the Field Erection Divisions whose whole-hearted assistance and cooperation contributed greatly to the successful prosecution of this work.

Packaging Welding Generators

Solving electrical power problems for field-welded structures by consolidating individual power requirements into one heavy-duty Diesel engine

by A. F. Fino

IN THE field erection of welded structures the problem is often encountered as to the source of power available for operating the mechanical equipment such as welding machines and air compressors. If electric power of the proper characteristics is available at the site, the problem is readily solved by using electric motor-driven machines. This is the simplest solution but not the most common as many structures are erected in areas not completely developed or too far remote to permit economical installation of an electric hook-up. In cases where temporary electrical connections are made, line transmission failures frequently occur which create considerable havoc with the production schedule.

Another means to attain power is to develop the electricity at the erection site with Diesel-generator units. This arrangement is satisfactory for large field installations requiring ten or twelve welders and several air compressors for each unit. A power consumption of this order can justify the cost of using a generator set at the site. The flexibility of machine movement required by different phases of the erection is somewhat limited by the length of the power transmission cable, and unless poles are used, a hazardous erection condition may develop.

On many of the smaller field installations it is common practice to use individual gasoline or Diesel engine-driven machinery. The equipment required for the erection of the 100,000-gal elevated tank shown in Fig. 1 usually includes three 400-amp welders, one 200-amp welder, and one air compressor of approximately 80 to 100 cu ft capacity. The five units are shown in Fig. 2. They cover an operating area of 176 sq ft and have a combined weight of 14,000 lbs. In order that costly downtime of the equipment is kept to a minimum, the five units require individual attendance, careful maintenance, and periodic inspections. Nevertheless, even with these precautionary measures, the operating cost ratio of the field equipment is a major item in the erection overhead cost.

A. F. Fino is Chief Design Engineer, Hammond Iron Works, Warren, Pa.

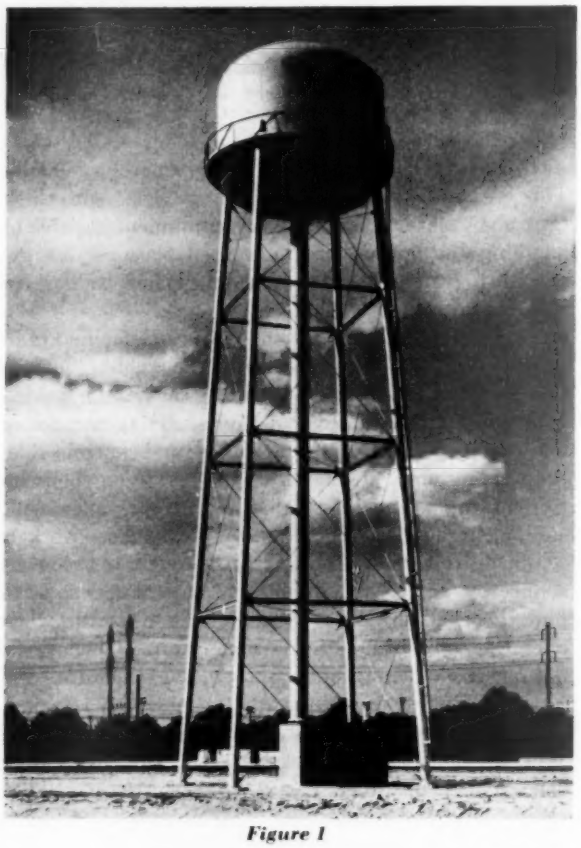


Figure 1

The equipment performance ratio can be controlled to some degree by integrating the component drive units into a unified mechanical source. Figure 3 shows a packaged arrangement capable of producing the same power output as the five machines shown in Fig. 2. A total working area of 67 sq ft with a weight of 11,100 lb is contained in the assembly. A higher operating efficiency, cheaper fuel, lower handling costs, compactness and long dependable operation are some of the factors originally influencing the package concept.

The possibility of a 135-hp Diesel engine driving a single welder demand of 30 hp or the continuous idling of four welders when the requirement is for air alone presented an economic problem as to operating effi-

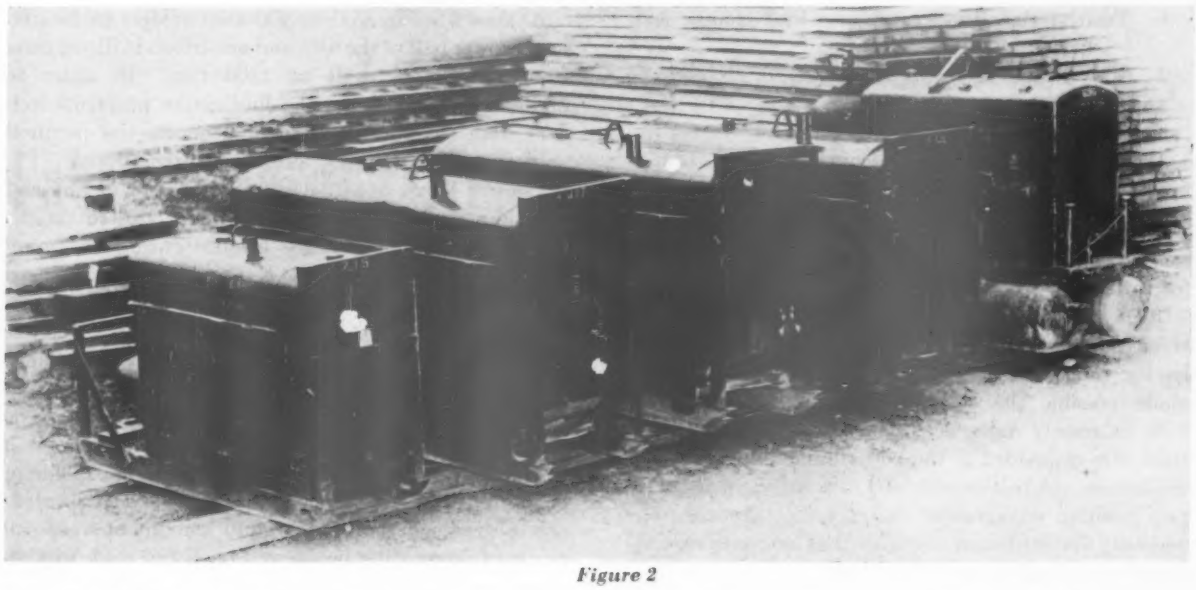


Figure 2

ciency. The multiple idling condition could be remedied by installing clutches to the shaft of each unit. A clutch installation of this type would add to the bulk and intricacy of the package and therefore was deemed as not worth while. A field equipment analysis has shown that wear resulting from idling is a relative minor item influencing the over-all maintenance cost.

The major factors entering into high cost of operation are:

1. Idle time of crew due to inability of motor starting.
2. Inefficient work resulting from poor performance of equipment.
3. Necessary field attendance.
4. Shop maintenance of equipment.
5. Handling and moving of equipment.

The package unit tends to minimize the effect of most of the above factors. The motor starting problem, however, could be more serious as five machines are involved rather than a single unit. By consolidating the individual power requirements of each machine into one heavy-duty Diesel engine, the difficulties usually causing light engine starting troubles are eliminated and more dependability is assured.

Probably the most difficult problem encountered in the package arrangement was the proper transmission of mechanical power to each machine. The following requirements were established for determining the proper drive:

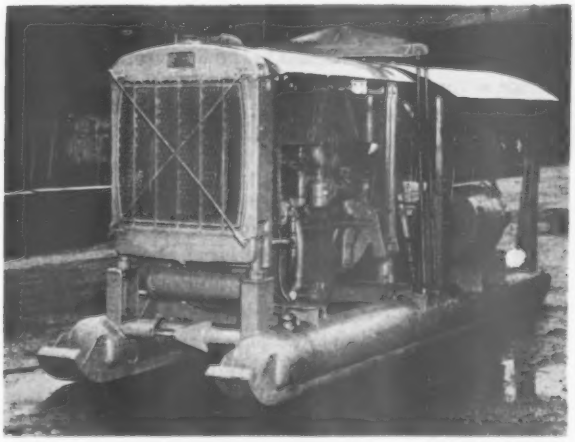


Figure 3

Figure 4

1. Positive drive under extreme load change conditions.
2. No stretch of transmission requiring periodic adjustment.
3. A minimum take-off bearing load.
4. No lubrication requirements.
5. Compactness and light weight.

The requirements listed were stringent but believed essential to insure a minimum of field maintenance and for satisfactory performance of the equipment.

The transmission arrangement adapted for this service is shown in Fig. 4. A wide synthetic rubber belt having molded-teeth engaging grooves in the pulleys made possible the combination of a nonslip drive with extremely light weight. A continuously wound steel wire embedded in the belt eliminated any stretch tendencies. A belt tension of 4 lb is sufficient to maintain positive engagement and thereby eliminate the necessity for outboard bearings that normally are required with high-tension belt loads.

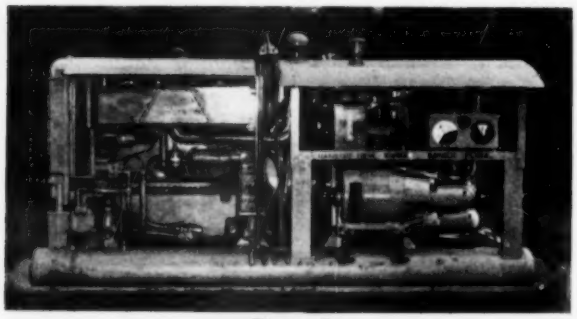


Figure 5

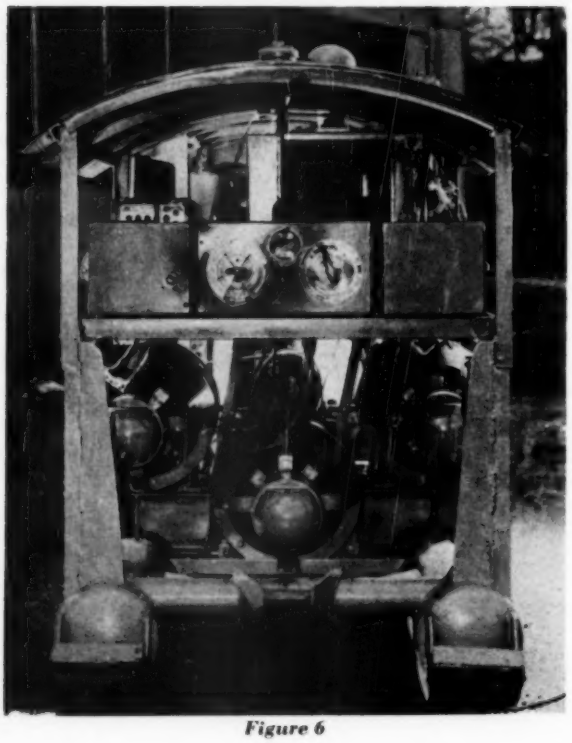


Figure 6

As shown in Fig. 5, three 400-amp welders are located in the lower half of the unit and are driven in direct ratio from the Diesel shaft at 1400 rpm. In order to minimize wear and bearing lubrication problems welders were selected that would generate the required amperage with the least number of revolutions.

Control boxes are conveniently located at the end and sides as shown in Figs. 5 and 6. Located on the control boxes are auxiliary electric outlets for small tools and lights. Current is provided by oversized exciters mounted on each generator armature shaft.

The selection of the air compressor for the unit required considerable attention. The size, weight, balance wheel arrangement, speed of rotation and delivery capacity were items which were carefully investigated. The unit shown in Fig. 7 (adjacent to control box) is a 15-hp compressor of aluminum construction capable of delivering 93 cu ft of air at 100 psi. By-pass valves are so arranged that a minimum amount of wear will occur while rotating in the system under no load.

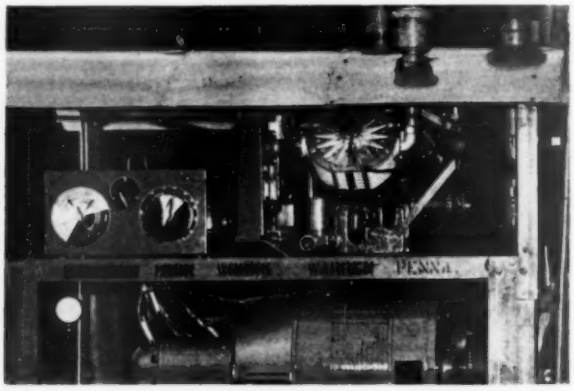


Figure 7

To further stabilize the air-compressor rotation inertia factor, the shaft of the compressor drives the 200-amp welder shown adjacent to the control box in Fig. 5. The 200-amp welder operates at 2600 rpm and is used primarily for fit-up phases of the erection.

The entire assembly is mounted on two tubular skids 12 in. in diam by 12 ft long. One of the tubular skids is used as the fuel tank for the Diesel engine and contains sufficient fuel for 16 hr of continuous operation. The second skid is the air-receiver tank for the air compressor. Skids are designed and stamped in accordance with the ASME Code for Unfired Pressure Vessels. The cost of the assembled package is approximately 10% greater than the units powered separately. This additional cost is readily absorbed with the first erection installation.

The stabilizing inertia of the large Diesel drive unit permits dependable power for uniform welds with "on-and-off" startings, a feature that is sometimes difficult to achieve in standard self-contained gasoline-driven units. The dependability of the packaged unit coupled with the handling and maintenance advantages have greatly improved the equipment performance factor for field installations.

Fabrication and Welding of Steel Penstocks

Fabrication techniques used in the construction of huge penstocks 19 ft in diameter varying from $^{5}/_{8}$ to $1^{1}/_{2}$ in. in thickness

by Robert F. Scott

INTRODUCTION

THE ever increasing growth of Canadian Industry in the Niagara Peninsula has been accompanied by a steadily growing demand for power. To meet the present increased need, and with foresight for the future, the Ontario Hydro Electric Power Commission embarked upon the project of diverting 15 million gallons of water per minute from the Niagara River above the Falls.

The water will pass through twin tunnels under the city of Niagara Falls, Ont., for a distance of $4^{1}/_{2}$ miles, then through an open cut canal for a distance of $2^{1}/_{2}$ miles to the forebay and power house site near Queenston. Twelve all-welded steel penstocks will take the water from the forebay, under the scenic highway, down a 60-deg, 300-ft incline into the scroll case speed rings. These speed rings are coupled directly to the huge turbines that will eventually generate 1,200,000 hp.

The penstocks are 19 ft in diameter, 495 ft long, and required a total of 6600 tons of steel and 150,000 lb of welding rod and flux for their construction. The upper section, about 100 ft long, was made of $^{5}/_{8}$-in. thick plate and is actually a tunnel liner as shown in Fig. 1. As the water head increases the plate thickness also increases, and at the bottom elbow a maximum thickness of $1^{1}/_{2}$ in. was used. This bottom elbow reduces in diameter from 19 to 14 ft, and the plate thickness also decreases from $1^{1}/_{2}$ to $1^{3}/_{16}$ in.

FABRICATION SEQUENCE

Since the construction site was close to the Fabricator's shop, it was economical to shop-construct complete penstock sections 8 ft long. These were shipped to the site, where additional assembly work was done before the sections were erected in place.

The first step in the shop fabrication procedure was to subject the steel plates to a close visual inspection,

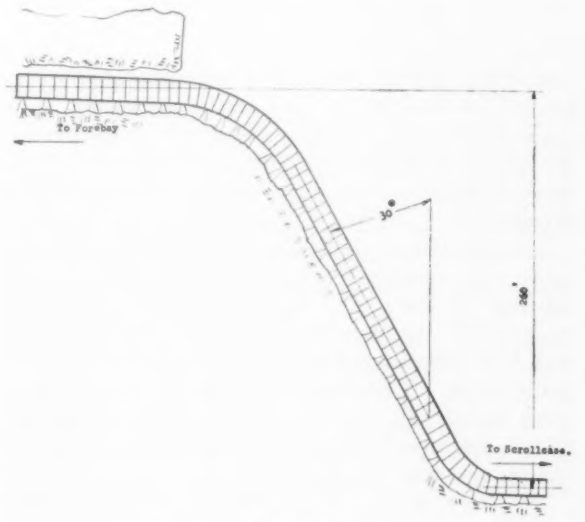


Figure 1

and to repair any minor defects found. Next the plates were marked and flame cut to exact size using automatic, triple-headed cutting machines. These simultaneously cut the land and both bevels on the plate edge for the welding grooves.

Figure 2 shows the typical welding groove details.

After cutting, each 8-ft wide and 31-ft long plate was shaped to form half of an 8-ft long cylinder. Two of these were fitted together to form a complete cylinder 19 ft, 2 in. in diameter. These cylinders were supported by an internal structure of radial rods. The purpose of these "spider rods" was to keep the cylinders round during transit and construction, and were removed from the inside of the completed penstock before the unit was put into service.

The welding of the longitudinal seams in the cylinders was done with a tractor type, automatic, submerged-arc welding machine, and the weld reinforcement was removed flush with the plate surfaces with manually operated, pneumatic chipping guns. Manual air grinders were then employed to grind the inside and outside surfaces perfectly smooth, and the finished surfaces were inspected for flaws.

An electric-driven low-temperature stress-relieving unit was used to stress relieve the welds before being

Robert F. Scott is with the Horton Steel Works Ltd., Fort Erie, Ont., Canada.

Presented at the AWS National Spring Meeting held in Buffalo, N. Y., May 4-7, 1954.

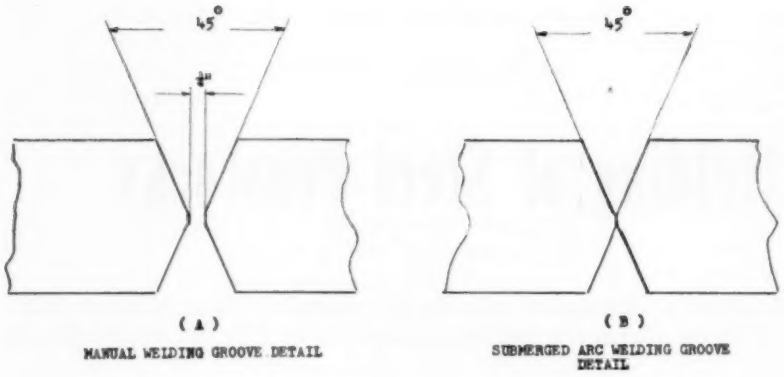


Figure 2

completely radiographed. The radiographs were examined for flaws in the weld, and if any repairs were required the rejected welds were carbon arc gouged for the extent of the flaw, rewelded, chipped and ground, stress relieved and the repaired area was again radiographed.

The next step in the fabrication sequence was to remove the completed rings from Fort Erie to the construction site. The rings were loaded onto semi-trailers with the diameters horizontal. The 8-ft high and 19-ft wide loads had to be escorted by a special police detail. The police escort lead a two or three truck convoy, guiding and directing traffic during the 25-mile trip over highway and construction roads to a storage area near the headworks.

The work at the subassembly site followed a procedure similar to that used in the shop. Two rings were fitted together, and the 16-ft long sections were then placed on the automatic rolls and welded together with the submerged arc method. The welds were chipped and ground flush, manually stress relieved and finally radiographed. Following a final inspection, the sections were taken to the headworks and a mobile crane lowered them into place.

The sections were then fitted for manual welding, and after welding the welds were chipped, ground, stress relieved, radiographed and repaired. The completed penstocks were covered with a 4-ft layer of reinforced concrete, and the final operation was the removal of the spider rods and the ladder rungs from the inside of the penstock. Figure 3 is a panoramic view of the project.

MATERIAL STANDARDS AND QUALITY CONTROL

Careful planning, leaving nothing to chance was the by-word for the complete project. Nothing was overlooked to keep the standards at the highest level.

Quality control began with the purchase of materials according to exacting specifications, and was continued during construction. It was completed by the use of welding procedures and sequences previously tested and qualified.

The material standards and quality control checks are enumerated in the order of use:

1. Plate material was ASTM, A-201 Grade A Firebox quality.
2. Mill test reports were required for all plates.
3. A visual check was made in the Shop of all plate surfaces and prepared plate edges for laminations, stringers or other defects.

Figure 3

4. The plates were carefully checked for size after flame cutting.
5. The rolling and shaping of the plates was constantly checked with sweeps and gauges.
6. Prior to welding, the steel was preheated to 300° F if the thicknesses exceeded 1 in., and all thicknesses were preheated if the temperature was below 50° F.
7. The welding operators were required to weld a test plate which, when radiographed, showed no flaws.
8. All welds were chipped and ground flush on each side to within 2% of the plate thickness.
9. The welds were low-temperature stress relieved.
10. All welds were completely radiographed.

As a result of the material standards and quality control methods employed, it was possible to produce a flawless structure that met with the exacting dimensional tolerances the specifications required.

PREHEATING

Several preheating methods were investigated in an effort to secure the most efficient and economical process. Tests indicated that a gas-burning unit, fueled by propane gas would be best suited for this work. A special design was necessary to produce a burning head that would be safe and simple to operate.

Two types of units with the same basic design were required. The units used in the Shop were straight sections, and for the field use they were circular in shape to fit the curvature of the penstocks. At the gas inlet a screw-operated mechanism controlled the gas supply to an inspirator. A length of 1-in. diam. tubing with blast tips spaced at 6-in. intervals was attached to the inspirator. The blast tips were mounted so the unit could be used either on the inside or the outside surfaces. This was accomplished by the use of street elbows that allow the tips to be rotated 180 deg. The intensity of the heat and the flame characteristics were controlled by a butterfly valve in the inspirator. It was found that gas pressures between 10 and 35 psi had very little effect on the normal performance.

A gas reservoir of 18 cylinders connected together with a manifold unit was located at the top of the cliff. The fuel was piped through $1^1/_2$-in. diam pipe down the length of the penstocks, and short sections of hose were attached to the individual burners. The simplicity of this system was evident in the fact that one man could operate and maintain as many as 24 heating sections, needing extra help only when the heaters were moved from seam to seam.

In order to preheat to 300° F, and maintain this preheat during the welding operations, four heating heads were required for each circumferential seam. The heads were hung by hooks, fitted into bars welded to the inside or outside surface of the penstock. The light weight and simple construction of the heads made the moving from seam to seam a very easy job, and required but a few minutes for each move.

SUBMERGED ARC WELDING

Setting up a welding procedure for the submerged arc welding of the sections in the Shop proved to be quite simple. A groove detail as shown in Fig. 2*B* was used and test welds were made and qualified. Little trouble was experienced with the production welding.

A complete welding shop setup was built as close as possible to the erection site, and two 8-ft long cylinders were welded together. Had it been possible to transport these 16-ft long, 19-ft diam sections from the Fabricator's shop in Fort Erie to the erection site, a subassembly site would not have been necessary. The rock on the cliff face was badly cracked and flawed, and the erection forces found it impossible to plan the lifting and placing into position of the various sections until the platforms for the crane were built and tested. The immediate problem was to establish a procedure that could be used, and would be applicable to both manual and submerged arc welding. The details shown in Fig. 2*A* had been proved by test to be acceptable for manual welding, and a revision of this detail, shown in Fig. 2*B*, allowed the use of the same welding groove with the plates fitted metal to metal.

Two 900-amp direct-current, motor-driven generators supplied the welding current. A tractor type welding head geared to travel between 9 and 20 ipm was employed to do the welding. Before any production welding was attempted, several test welds were made on 3-ft long plates of different thicknesses under actual field conditions. The first test welds were made using a manual root pass of E6020 electrode. The purpose of this was to increase the root base, and reduce the number of burn-throughs on the first side welded. It was found that this root pass could be eliminated by reducing the current density on the first side welded, and complete penetration was obtained on the second side welded by increasing the current density. During the testing period it was possible to obtain welds using a $^7/_{32}$-in. diam wire for all plate thicknesses. This however, proved impracticable on the actual welding, and a $^5/_{32}$-in. diam wire was used on all plates less than 1 in. thick in order to reduce the build-up. A set of rolls, powered by a variable speed motor, turned the sections at a speed that was synchronized with the welding head travel rate. Figure 4 shows the unit in operation. The small liquid level mounted on the flux hopper was used to aid in keeping the welding head at the exact position to allow the weld puddle to solidify in the downflat position.

Figure 4

Production welding was started after the tests were complete, and a few minor changes in current sittings and speed travel rates had to be made in the procedure. The same specifications applied to this work, and the welds were chipped and ground flush before stress relieving and radiographing.

MANUAL WELDING

Many types of welding electrode were investigated before deciding that E6013 had the best operating characteristics of all the E60XX groups in all positions. As a result of these investigations, the E6013-type electrode was chosen for all the manual welding of the sections together at the job site.

Ease of slag removal and high deposition rate prompted the choice of this material from a production view-point.

The radiographs of test welds showed excellent density and soundness. A groove detail identical to that used for the submerged arc welding was used. The only difference being that the plates were spaced 1/4 in. apart. The cold arc characteristics and shallow penetration of this type of electrode made this spacing necessary. A weld bead of sufficient size to withstand the cooling stresses could not be obtained with a smaller spacing or a smaller diameter electrode. A large weld deposit was also desirable in order to obtain a slow cooling of the weld puddle to allow the gases and slag enough time to evolve to the surface.

Training and testing of operators was carried out in a special section set up in Fort Erie, and as many as 20 men a week tried the welding test in the initial stages of the project. This test was revised several times as the work progressed, and finally the position chosen for a standard test was the one that appeared to be the most difficult, and where the greatest number of flaws were being found in actual practice. This particular position can be termed as horizontal overhead. The 1 1/4-in. thick and 1-ft long test plates were placed at an angle 60 deg from the vertical, with the axis of the weld horizontal. The overhead side was completely welded first. This was in keeping with the sequence used on the project. After the back side was gouged to sound metal, the weld was completed from the downhand side. The finished test welds were then radiographed, and the radiographs examined for flaws. Considering the adverse conditions at the job site, it was the opinion of everyone concerned that nothing but a perfect weld made under shop conditions could be accepted as qualification to an operator's ability.

It has been established that E6013 has the best and easiest operating characteristics of the E60XX group, and is considered to be the easiest of the E60 group to use. It was found that the technique required, though easier to an inexperienced operator, was just different enough that many experienced operators used to E6010 found it impossible to adapt their welding technique to suit the E6013 type.

After a short practice training period the operators performed the welding test, and if the work was acceptable he received further instruction at the site to help him produce work in keeping with the high standards set for this job. A crew of ten welders and two arc gougers worked under the supervision of a specially trained welding supervisor. Three such crews were able to work on three penstocks at the same time.

The welded seams were surface-conditioned, stress relieved and radiographed as quickly as possible after the welding was completed in order to utilize the radiographing not only as an inspection method but as a control on the quality of work being produced. Spot radiographs were also taken of the seams immediately after welding whenever there was any doubt of an operator's ability.

CHIPPING AND GRINDING

The reinforcements from both sides of the weld seams had to be removed. This meant that about 117,000 ft of weld reinforcement had to be removed flush with the plate surfaces. The chipping and grinding flush of these weld seams did not present much of a problem either in the Shop or at the subassembly site. All this work was positioned, and the chipping and grinding operation could be done in the easiest position. After the sections were welded into place at the erection site the chipping and grinding proved to be quite a problem. Some time was spent in training and screening workmen before a force could be built up to allow the work to progress satisfactorily. All burrs and gouge marks had to be chipped and ground flush. Any flaws in excess of 2% of the plate thickness were sufficient to show in the radiographs and confuse the interpretation of these films. Chipping and grinding in a semioverhead position from a scaffold that sloped approximately 30 deg from the horizontal was exceedingly difficult. A constant check on the work being done was the only solution in the production.

The banding effect of the longitudinal weld shrinking sometimes gave the impression of overgrinding and checks had to be made periodically with a straight edge to determine whether the concaved section was banded or over ground. Scheduling the work for the chipping crews was also rather difficult. This was due to the fact that a comparable number of man-hours were required to surface condition a thin section to what was required to chip and grind a section almost twice as thick. The number of man-hours needed to weld a heavy section was almost four times that required to weld the thinner plates. This meant that fewer chippers were required to chip and grind the weld surfaces on thick plate, but on the upper sections the number of chippers had to be tripled or the welding would get so far ahead of the radiographing that the use of radiographing as a control would be lost.

As the work progressed on three units simultaneously, it was possible to move the chippers and grinders from penstock to penstock as required. One man was

employed full time as a blacksmith, forging and grinding chipping tools for the surface-conditioning crew.

STRESS RELIEVING

The controlled, low-temperature stress-relieving method was used to stress relieve all welded seams. As mentioned previously, the stress relieving of the shop-welded seams was accomplished with the aid of an electrical-driven stress-relieving unit. All stress relieving in the field was done manually.

Whenever a weld is made, the union is accomplished by melting and forming together the welding rod and a portion of the base metal.

Between the liquid pool and a point some distance away where the base metal remains cool is a temperature drop ranging from the melting point of steel to room temperature. As the weld metal solidifies and cools to room temperature, the result is a shrinkage of the heated metal which imposes a compressive stress on the unheated portion of the base metal. The base metal being cold is able to resist this stress—and the weld metal and heat-affected base metal cannot shrink. The heated zone is then subjected to a tensional stress. The magnitude of the residual stress will be equal to the yield point of the heated metal in tension upon cooling.

For adequate stress relief the metal must be free to adjust itself under the action of the residual stresses. In the case of a welded seam this cannot take place, the unheated base metal restraining the heated portions. Since the magnitude of the residual stress can be reduced only by plastic flow, the yield point of the metal must either be lowered thermally or by superimposing, mechanically, a load greater than the yield point.

The low-temperature stress-relieving method makes use of the tension load in the weld to supply the mechanical loading by increasing this loading by heating a band 6 in. wide with the center line of the heated area 5 in. from the center line of the weld on each side of the weld to about 300° F above the original temperature of the steel. The temperature of the weld itself remains at or near its original temperature during the stress-relieving operation. The weld is kept cool with the use of a water spray approximately 6 to 8 in. back of the heating torches.

A predetermined speed was established, and in the shop the machine was set at a speed ranging from 6 to 20 ipm depending on the plate thickness, and the stress-relieving operation was then performed automatically. For the field operations, when the stress-relieving had to be performed manually, heat-sensitive crayons were used on the side opposite from where the heat was being applied, and as these crayons melted the speed of the operation was increased or slowed down accordingly.

Plates $1^1/_2$ in. thick required about 1 min to stress relieve 8 in., and the plates $^5/_8$ thick were treated at approximately 20 ipm.

For both the manual and machine stress relieving, two flame brushes were mounted into a single head. These brushes were spaced on a 10-in. center and the water-quench cooling followed 6 or 8 in. back. The position of the seams after the penstock sections were erected did not lend themselves too readily to the application of the water cooling, and some difficulty was experienced before a satisfactory sequence could be worked out. Cold weather plagued the operations when the water hose would freeze or the running water froze to the steel and scaffolding, making the area very dangerous. As with the preheating system, a battery or reservoir of 8 cylinders of acetylene and 8 cylinders of oxygen were connected to a manifold, and the gas supply piped down the cliff side, where intermediate stations allowed the use of relatively short lengths of hose from the gages to the stress-relieving heads.

ERECTION

The problems confronting the erection engineers were many and varied. In the early stages of construction the lower sections had to be erected from a Bailey Bridge structure. The sections, the heaviest being 15 tons, required a boom out radius greater than what was considered safe for the mobile hoist being used. In order to prevent this hoist from tipping over when the heaviest section, which incidentally was the furthest away from the Bailey Bridge structure, was placed, the hoist was guyed back to the powerhouse foundations. As the work progressed and the bottom sections were all in place these large hoists had to be walked up a gravel road about a mile and one-half long, and then over approximately one mile of the parkway highway. A heavy plank track was laid ahead of the hoist and no damage was done to the asphalt pavement. At the headworks bents of 12- x 12-ft timbers were built on the cliff face. This can be seen in Fig. 5.

The sections were transported with a low loader as shown in Fig. 6 from the subassembly site to the erection site. They were then lifted from this 8-wheeled vehicle and swung around and lowered over the cliff face onto tracks where, with the use of a stationary hoist anchored into the tunnel section, they were lowered into place.

As the sections were lowered into place, scaffold plank, welding rod and other equipment and material was loaded onto the sections to be lowered as the section slid down these tracks.

After the section was in place the initial work of connecting it to the steel already erected and fitted was done, and a check for center and elevation was made. The final adjustment to the proper elevation and center was done by using hydraulic jacks to lower or move the section from side to side. After the section was in its proper position it was then fitted with patented fit-up gadgets.

As in all the other operations involved in this proj-

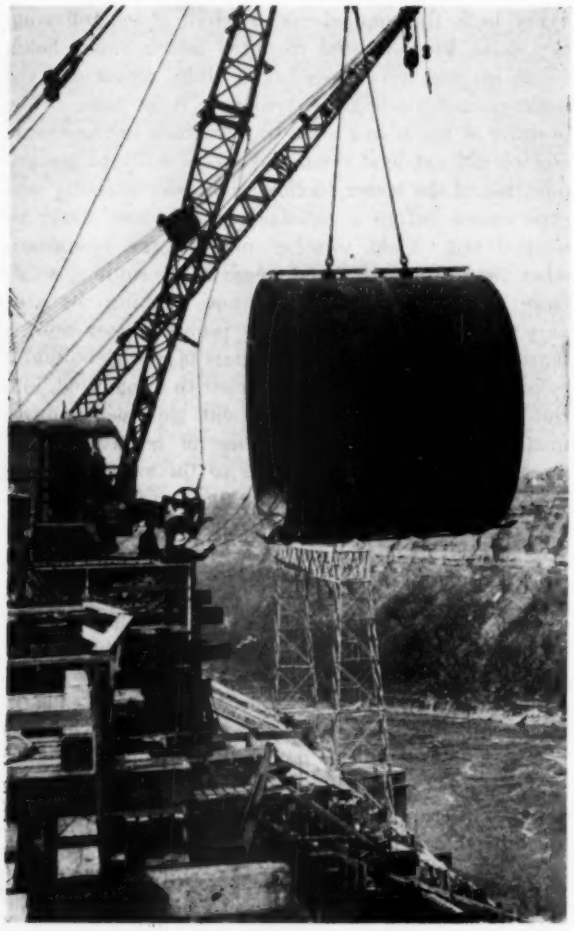


Figure 5

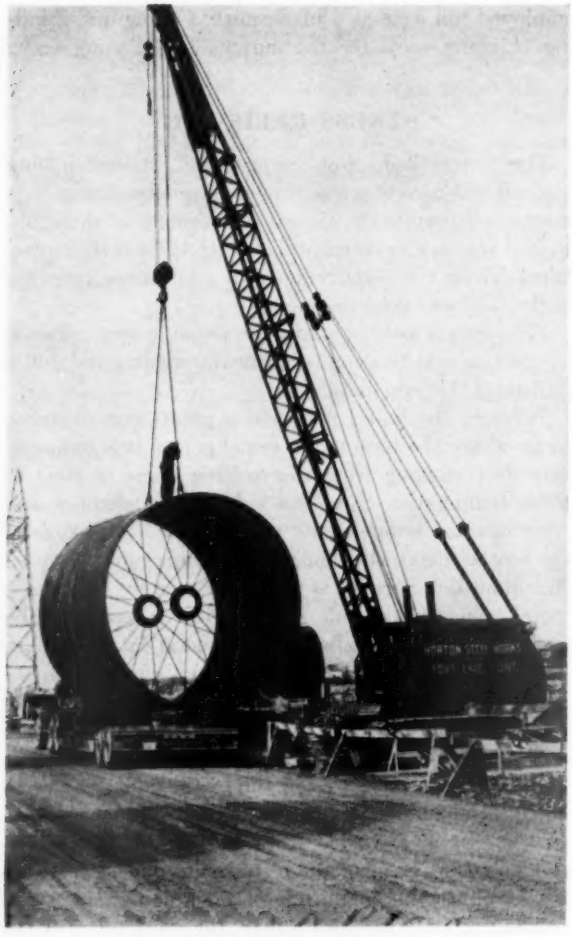


Figure 6

ect, tests were made of the equipment. The hoist was set up on a proving ground and various loads of a known weight were lifted with the boom-out radius being carefully checked for each of the lifts. In this way a known safety factor was established and all lifts were made successfully.

RADIOGRAPHING

Two methods were used to radiograph the finished welds. A radioactive isotope was used to supply the radiation source for the radiographing of the shop welds, and a 250-kva X-ray tube was used to radiograph the welds made in the field. In both methods the whole seam was taken with one exposure. The 8-ft long welds in the Shop, two of these to a section equaling 16 ft were radiographed at one time. In the field radiographing, a whole circumference of 60 ft was radiographed at one time. Forty-four 17-in. films were placed around the outside of the penstock sections and were held in place with a rope that was kept tight with a 2- or 3-ft long spring. The radiographs, after exposure, were processed and the films carefully examined for flaws. Any films not showing the 2% penetrameters were rejected. Also cause for rejection were film flaws, watermarks, scratches, etc. After the radiographs were accepted they were sent to the head office of the Hydro Commission and placed on file for future reference.

LAMINATIONS, STRINGERS, ETC.

Several laminations were discovered as the work progressed. A constant check on the steel from the time it was rolled right through the fabrication and erection processes sometimes failed to discover these flaws until after the sections were in place. Whenever any of these separations in the plate were discovered the supersonic method was used to map out the area where the flaw had been discovered originally. If the flaw was within certain limits the section was then cut out and an insert plate of the same thickness and material was used to fill the cutout. The back step and cascade welding sequence was employed to reweld these inserts, and a light peening was used to aid in reducing the residual stresses in the weld to prevent cracks. The same procedure employed for the welding of these inserts as for the rest of the penstocks was used and the finished work presented a smooth, flawless joint.

If these flaws were over a given limit the whole ring was cut free and brought back to Fort Erie where the plates were cut apart and new plates were fabricated and replaced the flawed sections.

CONCLUSIONS

Many very important things were learned from the welding and erection of this project. A need for qualified procedures was more than evident. Every step must be carefully planned in the Engineering Department, proved in the laboratory and further proved in actual practice. Personnel must also be experienced and qualified. A constant educational program is necessary. After the qualification of a welding operator it was found that he cannot be put to work on his own, but a constant check and a plan of instruction must be followed to produce the type of work that is being required on more and more projects. Many ideas and methods may seem to be perfect in the planning stage, but are disproved in the laboratory, and still other ideas that are proved in the laboratory can be disproved in practice.

It is hoped that the lessons learned and the ideas incorporated into the welding of this project may serve to further the advancement of the Welding Industry into larger and more complex structures. It is also hoped that this may further prove that the use of welding as a tool can, with the proper engineering methods, careful quality control, adequate training of personnel and proper inspection methods, equal any other method known to join structures of any size and shape.

ACKNOWLEDGMENTS

Submerged arc welding, Lincoln Electric Co. Low-temperature stress relieving, Linde Air Products, Photography, Hydro Electric Power Commission Photographic Department, Radiographing, Industrial X-Ray and Isotope Ltd. of Canada.

Current Welding Literature

(*Continued from page 642*)

ment, I. R. Bartter. Industry & Welding, vol. 27, no. 3 (Mar. 1954), pp. 37–40, 68, 70–71.

Electrode Materials for Resistance Welding, W. J. Armstrong and H. D. Baer. Welding & Metal Fabrication, vol. 23, no. 3 (Mar. 1954), pp. 95–97.

Electrodes. Powdered Iron Invades Electrode Design, L. K. Stringham. Iron & Steel Engr., vol. 31, no. 3 (Mar. 1954), pp. 127–128.

Flash Welding Eliminates Rejects. Industry & Welding, vol. 27, no. 1 (Jan. 1954), pp. 76–78.

Industrial Plants. Welded Tubular Steel Structure. Civ. Eng. (Lond.), vol. 49, no. 571 (Jan. 1954), p. 62.

Inert Gas. How to Weld Aluminum-Bronze to Steel, L. H. Hawthorne. Industry & Welding, vol. 27, no. 3 (Mar. 1954), pp. 50–52, 54.

Inert Gas. Weld Aluminum Die Castings with Inert Arc Process, R. Haslip. Industry & Welding, vol. 27, no. 1 (Jan. 1954), pp. 33–36.

Inert Gas. Self-Adjusting Welding Arcs, J. C. Needham and W. G. Hull. Brit. Welding J., vol. 1, no. 2 (Feb. 1954), pp. 71–77.

Light Metals. "Slope Control" Lengthens Tip Life and Improves Weld Quality, C. Bruno. Industry & Welding, vol. 27, no. 3 (Mar. 1954), pp. 44–46, 67.

Metals and Alloys. Hard Facts About Hard Facing, J. Wischhusen. Industry & Welding, vol. 27, no. 2 (Feb. 1954), pp. 49–53, 55, 84–85.

Mining Equipment. Welding and Efficient Maintenance, C. W. Brett. Mine & Quarry Eng., vol. 19, no. 12, (Dec. 1953,) pp. 461–464.

Motor Cycles. Progress in Motor Cycle Frame Production, R. Fern. Welding & Metal Fabrication, vol. 22, no. 3 (Mar. 1954), pp. 86–89.

Motor Truck Manufacture. World's Biggest Truck Built by Welding, T. B. Jefferson. Welding Engr., vol. 39, no. 3 (Mar. 1954), pp. 32–33, 35.

Natural Gas Pipe Lines. Weld 17-mile Pipeline in 7 Days. Industry & Welding, vol. 27, no. 2 (Feb. 1954), pp. 101–102, 104–105.

Oil Tanks. Why Storage Tanks Fail, F. J. Feely, and M. S. Northup. Oil & Gas J., vol. 52, no. 39 (Feb. 1, 1954), pp. 73–77.

Oxygen Cutting. Use of Oxyacetylene in Rolling Mills, R. L. Deily. Iron & Steel Engr., vol. 31, no. 3 (Mar. 1954), pp. 83–90.

Oxygen Cutting. Which Flame Was Faster? F. W. Sowa and W. C. Truckenmiller. Welding Engr., vol. 39, no. 3 (Mar. 1954), pp. 43, 48.

Pipe Manufacture. Atomic Energy Production Requires Nickel-Plated Pipe, E. A. Altholz. Machy. (N. Y.), vol. 60, no. 7 (Mar. 1954), pp. 166–172.

Pipe Lines. Inert Gas Welding Applied to Pipe and Tubing, R. E. Lorentz, Jr. Combustion, vol. 25, no. 6 (Dec. 1953), pp. 41–45.

Pressure Vessels. Shipyard Welding "Know-How" Pays Off in Industrial Fabrication, R. H. Quist. Industry & Welding, vol. 27, no. 3 (Mar. 1954), pp. 102, 104–105.

Radar Antennas. Magnesium—In Airborne Radar Systems. Modern Metals, vol. 10, no. 2 (Mar. 1954), pp. 36–37.

Radio Equipment Manufacture. All-Welded Aluminum Radio Housings are Strong, Light Weight and Leak Proof. Industry & Welding, vol. 27, no. 2 (Feb. 1954), pp. 82–83.

Resistance Spot Welding of $^3/_{16}$ and $^1/_4$ in. Mild Steel, J. E. Roberts. Brit. Welding J., vol. 1, no. 3 (Mar. 1954), pp. 136–140.

Resistance Welding of Coated Mild-Steel Sheet, A. J. Hipperson. Sheet Metal Industries, vol. 31, no. 323 (Mar. 1954), pp. 211–218.

Ships, Reconditioning. Tricky Problems in Welded Ship Repair, M. Forman. Am. Soc. Naval Engrs.—J. Vol. 66, no. 1 (Feb. 1954), pp. 185–193.

Ships, Reconditioning. Under-Water Welding, D. Brooks. Shipbldr. & Mar. Engine-Bldr., vol. 61, no. 547 (Feb. 1954), pp. 105–107.

Steam Pipe Lines. High-Frequency Butt Welding of Pipes for Steam Coils, C. B. Clason. Welding Engr., vol. 39, no. 3 (Mar. 1954), pp. 24–26.

Steel Structures, Welded and Cast Combined. Cast-Weld Construction, J. H. Hall. Foundry, vol. 82, no. 3 (Mar. 1954), pp. 114–119.

Steel Weldability. Effect of Hydrogen on Continuous-Cooling Transformation Diagram for Manganese—Molybdenum Steel, C. L. M. Cottrell. Iron & Steel Inst.—J., vol. 176, pt. 3 (Mar. 1954), pp. 273–282, 1 supp. plate.

Steel Weldability. Testing Steels for Weldability, R. G. Braithwaite. Brit. Welding J., vol. 1, no. 2 (Feb. 1954), p. 70.

Stud. Production-Line Stud Welding Cuts 30% From Fastening Costs. Industry & Welding, Vol. 27, no. 2 (Feb. 1954), pp. 115–116.

Titanium. Welding of Titanium, F. H. Stevenson. Tooling & Production, vol. 19, no. 12 (Mar. 1954), pp. 62, 65.

Trusses, Welded Steel. Use All-Welded Trusses for Freedom in Plant Design. Industry & Welding, vol. 27, no. 1 (Jan. 1954), pp. 45–47, 64.

Water Pipe Lines, Construction. Two-Hour Pipelining, R. Day. Excavating Engr., vol. 48, no. 2 (Feb. 1954), pp. 20–24, 59.

Welding, Electric Arc. High Speed Cinematography Determines Droplet Size in Arc Welding, P. C. van der Willigen and

(*Continued on page 679*)

Consumable Insert Method of Root Pass Welding

Butt welding plates or pipes with the inert-gas-shielded tungsten arc without the use of backing rings or bars

by Theodore A. Risch and Alfred E. Dohna

Abstract

This paper describes a new method* of butt welding plates or pipes without the use of backing rings or bars. The method allows an easier manipulation by the operator of an inert-gas-shielded tungsten arc torch to fuse completely, to the parent metal, a filler rod of controlled dimensions and composition which is inserted between the root faces of the butt joint. This technique gives a bright, smooth, crevice-free reinforcement weld surface on the far side of the joint in all positions of welding. Further, this method is insensitive to burn-through of the root pass for all materials on which it has been applied. The joint preparation allows the use of pipe and tube manufactured to commercial tolerances of wall thickness and diameter. The operator training required to obtain quality joints by this method is not excessive. Most welders with a nominal amount of experience with the inert-gas-shielded tungsten-arc process can qualify quickly for this method.

DESCRIPTION OF METHOD

FOR many years, welding fabricators and designers have searched for a dependable and practical method of welding pipe butt joints without the use of backing rings (Fig. 1). In more recent years, the demand for piping systems to carry highly corrosive fluids, to attain higher rates of flow with less turbulence and, even more recently, to carry radioactive materials without entrapment in crevices has caused an accelerated pace of development for a no-backing ring pipe butt joint. This paper describes a new method for achieving, in any butt joint of weldable pipe materials, a metallurgically sound root weld deposit having a completely fused internal weld of controlled contour. This method is called the consumable insert method of root pass welding. The principles described here are applicable to linear welds in all positions as well as to circumferential welds in pipe or cylinders. To keep this paper brief, the method described applies particularly to circumferential welds in pipe. Also, since this method may be applied to many material types, brevity dictates that this discussion be limited to one material—Type 347 fully austenitic seamless drawn pipe.

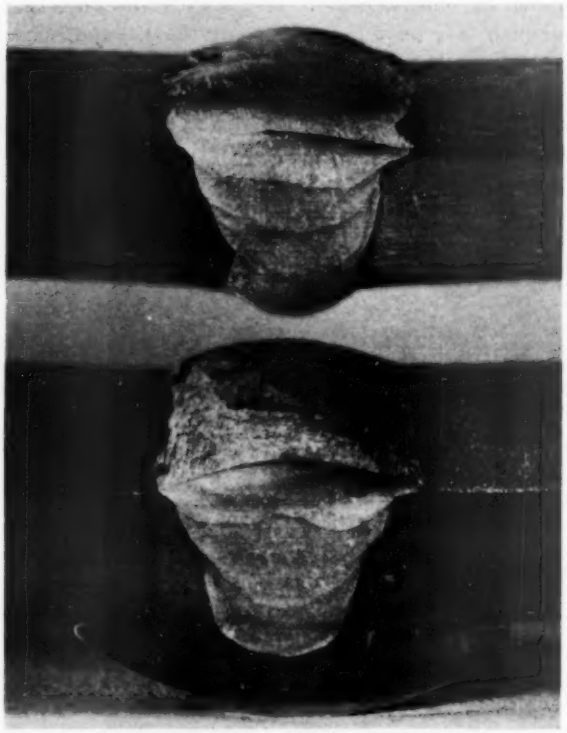


Fig. 1 Comparison of the insert versus the backing ring. Note insert has become integral part of the weld structure

Joint Requirements

The requirements for a method of welding a pipe butt joint without a backing ring may be summarized as follows:

Theodore A. Risch is Welding Superintendent and **Alfred E. Dohna** is Chief Inspector of the Electric Boat Division of General Dynamics Corp., Groton, Conn.

Presented at the AWS National Spring Meeting held in Buffalo, N. Y., May 4–7, 1954.

* The consumable insert and the consumable insert method of root pass welding are the subjects of patent claims which are pending in the U. S. Patent Office.

(*a*) The joint design shall require a preparation of pipe ends to tolerances within the reach of normal machine shop practice and compatible with the tolerances on wall thickness and circularity of pipe produced to commercial standards.

(*b*) The weld deposit composition shall be control lable in order to obtain the desired weld structure. The addition of filler material of a predetermined composition shall be made at a uniform deposition rate in order that the proper weld structure and composition will be assured throughout the weld.

(*c*) The joint shall be readily assembled and held in proper alignment for welding. The fit of the joint shall be such that some misalignment between parts is allowable without inhibiting the quality of the finished weld.

(*d*) The method shall be applicable for all position welding—downhand, vertical and overhead—under field conditions of limited accessibility to the joint.

(*e*) The surface of the weld inside the pipe shall be smooth and well blended into the adjacent pipe wall. The amount of internal weld reinforcement from all positions of welding shall be virtually the same with little or no protrusion into the flow stream within the pipe.

(*f*) Complete penetration shall be attained consistently with no danger of burning through the weld puddle.

(*g*) The finished weld shall be such that its characteristics are discernible by radiography to the same quality standards as those which apply in the radiographic examination of the more conventional methods of welding.

(*h*) Destructive tests of weld samples shall exhibit bend, tensile, macro and micro properties equivalent to, or better than, the same properties in joints welded by the conventional methods of welding.

(*i*) The method of welding shall be adaptable to automatic welding.

Consideration of the foregoing requirements indicates that some are necessary but all are desirable if advantages are to be realized in eliminating backing rings for butt joints.

Joint Design

The joint design to be used for applying the insert method of root pass welding for wall thicknesses greater than 0.215 in. is as shown in Fig. 2. The bevel angle may be changed to close the joint and decrease the amount of filler material required to complete a joint

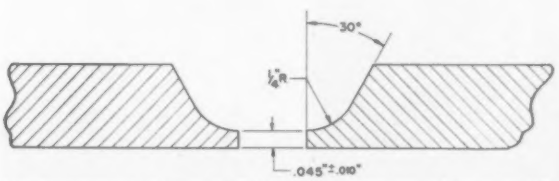


Fig. 2 Joint design with U bevel for consumable insert for wall thickness greater than 0.215 in.

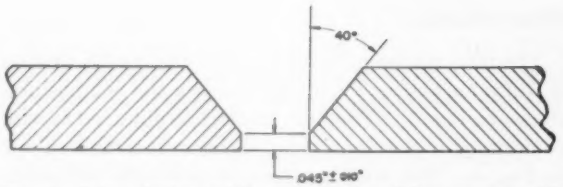


Fig. 3 Joint design with straight bevel for consumable insert with wall thickness less than 0.215 in.

in heavier walled pipe. The joint configuration may be altered above the tangent line to the 1/4-in. radius arc in any manner which will permit torch accessibility. The joint preparation of Fig. 3 is recommended for pipe having a wall thickness less than 0.215. The inside diameters of the pipes at the root face intersection may differ or may be eccentric to allow misalignment at any point of as much as 0.030 in. without any noticeable effect on the quality of the joint or the internal weld contour.

FILLER MATERIAL

The filler material to be used will have the following chemical composition:

Carbon	0.08 max
Chromium	19.0–22.0
Nickel	9.0–11.0
Columbium	10 XC min, but not more than 1.00%
Manganese	1.5–2.5
Silicon	0.25–0.75
Phosphorus	0.03 max
Sulfur	0.03 max
Tantalum	0.10 max

The above composition will yield a weld deposit having an average ferrite content of 6–8% to Schaeffler's diagram.

Fig. 4 AISI Type 347 filler material composition for consumable insert wire that will yield the desired ferrite content

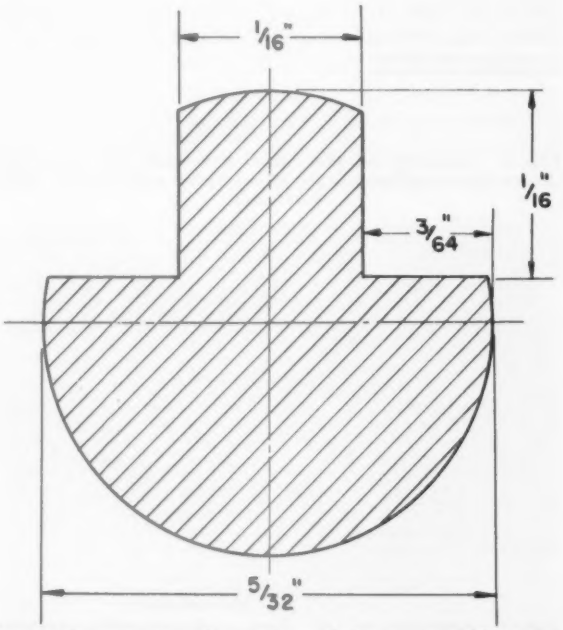


Fig. 5 Cross-section dimensions of the consumable insert wire

Filler Material

The filler material found to yield the results desired on fully austenitic Type 347 pipe has the composition shown in Fig. 4. The filler material is obtained as wire conforming to the dimensions of the cross section shown in Fig. 5. The wire is rolled to the inside diameter of the pipe leaving approximately $^1/_2$ in. of overlap length for trimming at assembly of the joint.

Joint Assembly

Assembly of the joint shall be accomplished within the dimensional allowances of Figs. 6 or 7 as applicable. Excessive diameter differences between joint halves can be compensated for by an insert which has been machined to steps of different diameters to give a fit within the prescribed tolerances. The assembly sequence consists of fitting the insert to one pipe end to obtain the trim-off point at the split in the insert. Trimming the insert should result in a tight butt of the insert ends for best results but in no case should the gap between the ends of the installed insert be greater than $^1/_{32}$ in. if clear radiographic results are to be expected at this point. The second pipe then should be assembled to the insert.

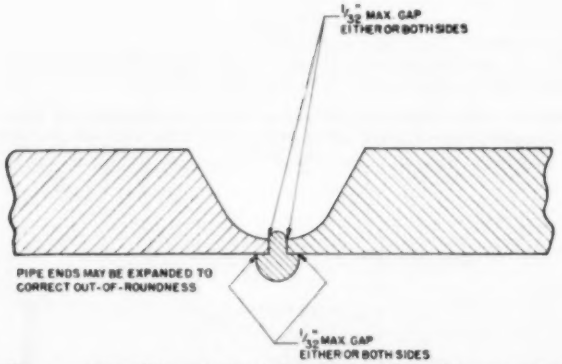


Fig. 6 Assembly of the joint with allowable excessive dimensional differences for fit-up (pipe wall greater than 0.215 in.)

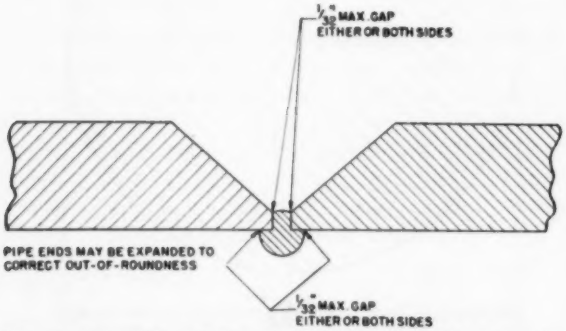


Fig. 7 Assembly of the joint with allowable excessive dimensional differences for fit-up (pipe wall less than 0.215 in.)

Welding Setup

All tack and root pass welding is accomplished using the inert-gas-shielded tungsten-arc process. The pipe purging and torch gas used in the development of this method was argon. It is the opinion of the authors that a slightly greater surface tension effect on the molten weld is obtained using argon rather than helium. Approximately 10 cfh of argon should be metered through the torch head for effective shielding in a still atmosphere. Increased air turbulence will require an increase of torch gas to maintain effective shielding of the weld. Argon purging gas is used for all welding including passes made after the root is closed if a clean, bright internal weld surface is desired. The purging gas shall flow through the pipe over the internal surface of the weld area in sufficient volume (approximately 15 cfh for 8-in. schedule 40 pipe) to displace the air adjacent to the weld. The purging gas shall be vented so that no appreciable back-pressure is built up behind the weld when depositing the root pass. Gas pressure behind the root pass will tend to cause the molten pool to blow out because of the relatively snug fit of the insert to the pipes.

The torch electrode to be used is a $^1/_{16}$-in. diam thoriated tungsten electrode sharpened to a long-taper point. The arc voltage for tack and root pass welding should be approximately 10 v. The ampere settings should be made to give 60 to 75 amp of straight polarity direct current. For welding in all positions, the torch should be held normal to the weld area with the electrode pointing to the axis of the pipe (Figs. 8, 9 and 10). The torch electrode point should be set about $^3/_{16}$ in. from the face of the torch cup.

Fig. 8 Proper relation of electrode to joint for fusion of the consumable insert in horizontal position

Fig. 9 Typical size and contour of good tack welds

Tack Welding

The assembled joint then is tack welded to hold the parts in position for root pass welding (Fig. 9). The tack welding operation consists of purging the tack with argon by means of a small cone which is held over the tack area and then fusing the pipes to the insert at approximately 2-in. intervals around the joint. Each tack should be as small as possible. For all welding, the arc should be struck on a bar clamped next to the joint and then moved to the point of welding (Fig. 10). Each time the arc is to be broken, the torch should be moved deliberately away from the molten pool so as to break the arc up on the bevel or, better still, off the edge of the striking bar. This technique will minimize craters and the so-called "crater cracks" that are sometimes associated with craters. One of the tack welds should be located at the split where the insert ends butt together so as to fuse these ends. Figure 9 shows an assembled, tack-welded joint ready for root pass welding by the consumable insert method.

Fig. 10 Proper relation of electrode to joint for fusion of the consumable insert in vertical position

Root Pass Welding

The consumable insert welding process requires a complete purging of the pipe with an inert gas during the welding of the root pass. The root pass sequence need not follow a set pattern although most operators have a preference for starting the weld at the bottom of the joint, in the overhead position, and welding up first one side then the other. As in tack welding, the arc is struck on a bar next to the joint and carried quickly down to the point of welding (Fig. 10). Although the arc length is not critical, the best technique appears to be to hold an arc length about $^1/_8$ in. long to attain the optimum fusion control, to minimize operator fatigue and lessen the chances of "shorting out" and causing tungsten inclusions in the weld.

Once the arc is established, the operator uses a very slight weaving motion of the torch to distribute the heat across the insert to both halves of the joint. As the metal becomes more fluid, the heat penetrates deeper until a definite rise of the molten pool occurs. As soon as this rise takes place, the operator should move the torch ahead along the joint at a uniform rate to assure complete penetration of each increment of the joint. The rising of the molten pool indicates that complete penetration has been achieved and is considered to be due to the surface tension forces of the upper and lower surfaces of the molten pool. These forces tend to equalize between the top and bottom surfaces to form an approximate sphere of molten metal. With the higher surface tension of cooler metal on the inside of the pipe, and the lower viscosity of hotter metal on the torch side of the pipe the net result is that the pool rises toward the torch or hotter side. A slight reinforcement bead is formed, thereby, on the inside of the joint. This reinforcement is uniform and smoothly blended into the parent metal surfaces (Fig. 11).

Fig. 11 Smooth contour of fused insert on interior of pipe. Note unfused insert

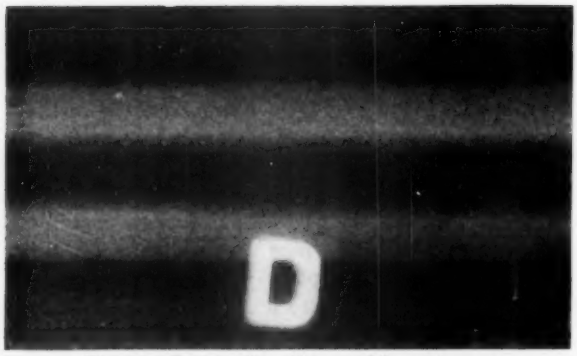


Fig. 12 Water-clear X-ray of fused insert

At the completion of the weld, the arc should be broken by moving the torch sideways up the bevel of the joint in the same manner as was described for tack welding.

Root Pass Inspection

Upon completion of the root pass of the joint, the joint may require a light wire brushing using a clean stainless steel brush before inspection operations are conducted. Normal inspection of the root pass consists of a close visual inspection with the aid of a dyed oil penetrant of the outside surface of the weld to verify that there are no craters evident in the surface.

In the early stages of producing welds by this method, it was considered prudent to examine the root pass by radiography (Fig. 12) to satisfy oneself that defects seen in the finished weld radiographs were not in the root pass or were known acceptable defects of the root pass. Root pass radiographs showed markedly light areas approximately the width of the original insert (Fig. 13). These were found to be portions of the insert which were not fused due to the failure of the operator to dwell long enough to note the rise of the molten pool before moving along the weld. Such areas were readily repaired by re-fusing the area until the rise of the molten pool was noted.

Finish Welding

After the applicable inspection operations of the root pass have been completed, the remainder of the joint may be completed using the inert-gas-shielded arc process and adding filler material of the same composition as that of the insert or by using the metallic arc process with a coated electrode. The pipe wall thickness will dictate the more economical method to use. The consumable insert method results in a fused root pass which averages $^1/_8$ in. in thickness (Fig. 14) so that the initial passes, using metallic arc and coated electrodes of the normal size, should be deposited with the same care as is used when depositing on a standard $^1/_8$-in. thick backing ring (Fig. 15). Regardless of the process to be used in finishing the joint, the inside of the pipe should be purged of air throughout the welding using an inert gas if a bright, oxide-free internal weld surface is desired.

Finish Weld Inspection

Completed production welds are subjected to the normal nondestructive inspections of dyed oil penetrant checking of the finished reinforcement and radiography. All development and production joints welded according to these procedures have produced fully acceptable radiographs having considerably greater clarity than would be expected from a like number of conventionally welded joints using backing rings. One phase of the development included the welding of test samples having intentional defects for the purpose of establishing radiographic standards for this process. From this phase of development the radiographs shown in Fig. 13 were chosen. As noted in the figure, the defects shown are areas of varying degrees of lack of fusion of the insert. The prominent white areas show the definite straight edges of the insert which did not rise into the joint at all. Other white areas have less well-defined edges indicate a partial rise of the insert into the joint. Obviously, when defects such as those shown in Fig. 13 are apparent in the root pass radiographs, they are repaired by re-fusing of the area until the phenomena of the molten pool rising is noted.

Operator Training and Qualification

The successful welding of two joints using the insert

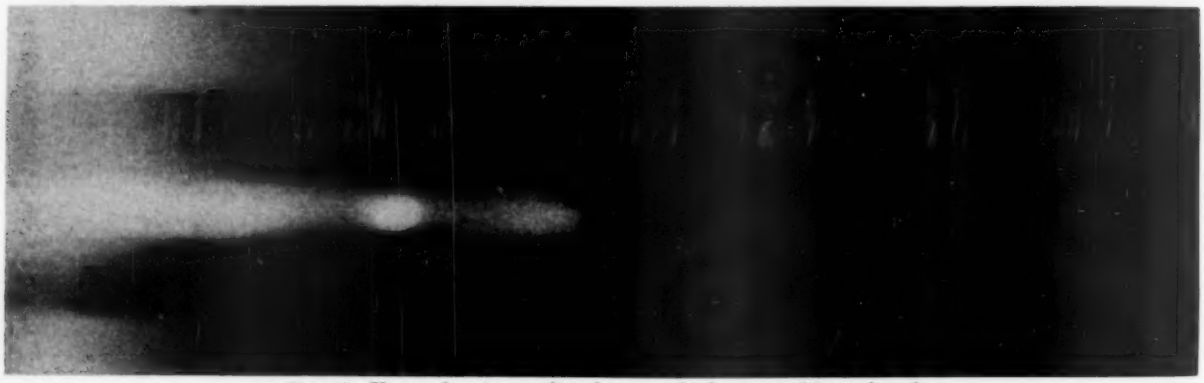


Fig. 13 X-ray showing unfused areas which are readily re-fused

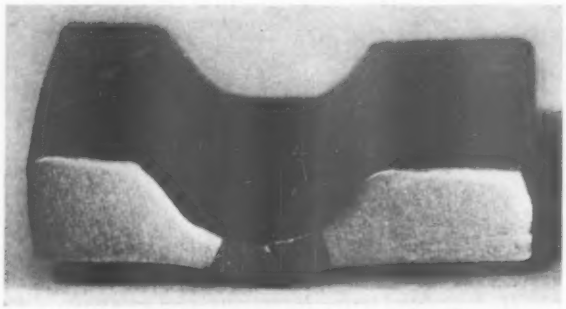


Fig. 14 Consumable insert results in a fused root pass. Note thickness of initial pass

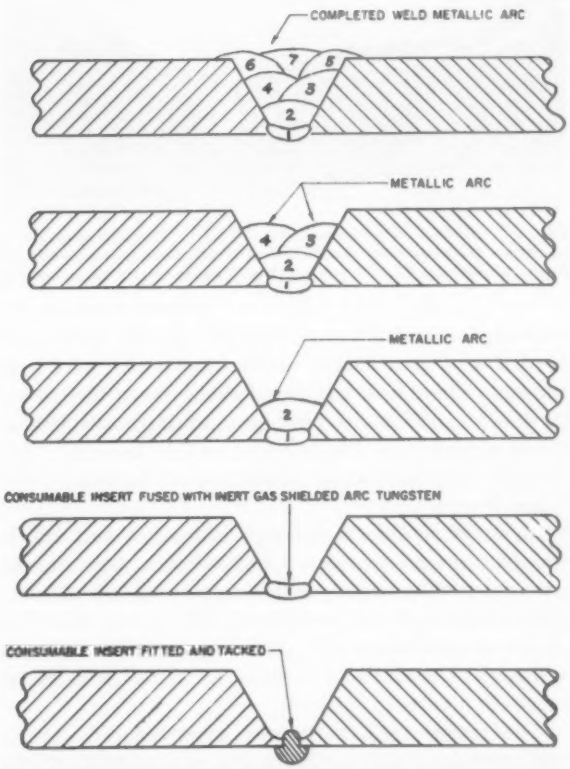


Fig. 15 Process used in finishing the joint—pipe is purged throughout all welding

method for making the root pass in the fixed horizontal position with the standard Navy accessibility restrictions (Fig. 4 of Section E-1, Appendix VII, General Specifications for Inspection of Material, USN) constitutes the qualification requirements for this process. Qualification samples are radiographed and then are cut into face- and root-bend specimens for bending in a standard bend jig. Radiographs must be free of all defects such as lack of complete fusion of the insert, tungsten inclusions and any evidence of craters or cracks. The bend specimens shall show no evidence of separations, cracks or fissures either at the parent metal fusion line or in the weld metal (Figs. 16, 17, 18 and 19). Operators who have experience in using the inert-gas-shielded tungsten-arc process can readily pass the qualification requirements after practice welding two or three joints. Operators whose experience has been limited to the metallic arc process on pipe usually require the normal amount of all-position practice with the inert-gas-shielded tungsten-arc process plus the welding of six or eight pipe test joints in the fixed horizontal position before they are ready to weld the qualification test samples.

Fig. 16 Root-bend test, 180-deg bend. Bend specimens show no evidence of crack, separations or fissures either at the parent metal fusion line or in the weld metal

Fig. 17 Face-bend test, 180-deg bend. Bend specimens show no evidence of crack, separations or fissures either at the parent metal fusion line or in the weld metal

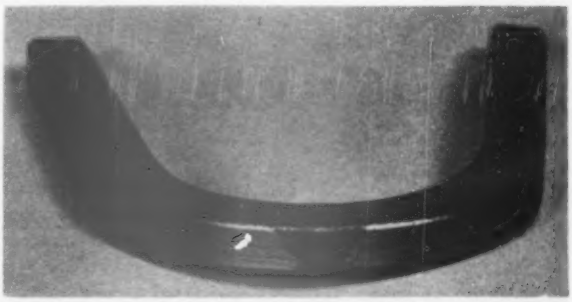


Fig. 18 Side-bend test, 180-deg bend. Bend specimens show no evidence of crack, separations or fissures either at the parent metal fusion line or in the weld metal

Fig. 19 Free-bend test. Bend specimens show no evidence of crack, separations or fissures either at the parent metal fusion line or in the weld metal

DEVELOPMENT DETAILS

The foregoing procedures for welding pipe butt joints by the consumable insert method of root pass welding were evolved from a development program which, when completed to the stage reported in this paper, had absorbed many months of intensive work and 500 pipe joints and test plates.

This program is still progressing. The variables of the method, such as arc voltage, amperes, insert dimensions and composition are being established or confirmed for additional materials. Certain details of this development program are interesting and noteworthy in evaluating the procedures outlined above. A discussion of pertinent details follows.

Destructive Testing

Obviously the first verification of the method was sought in the destructive testing of samples of pipe and plate. Test joints were made for all positions of welding from which the standard ASME Code and U. S. Navy specification bends and tensiles were machined. The bend tests performed were the root-, face-, side- and free-bend tests conforming to the ASME Boiler code Section IX and Section E1, Appendix VII, General Specification for Inspection of Material, USN (Figs. 16–19).

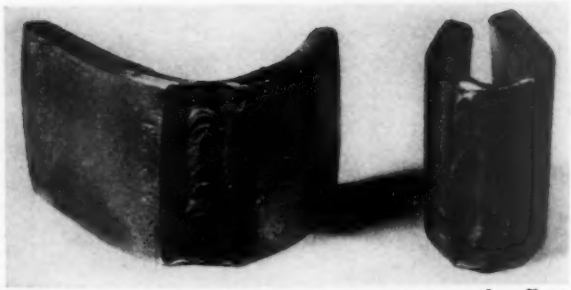


Fig. 21 Face-bend tests. Insert ring, root pass only. Face bend of the root pass only in the unconventional test shows no evidence of cracks or fissures

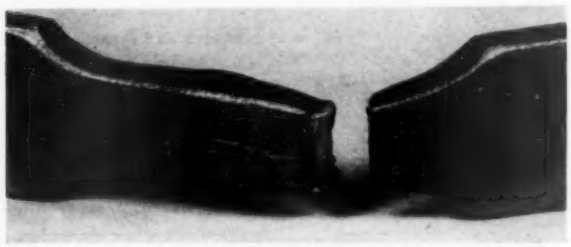


Fig. 22 Reduce tensile test 87,520 psi. Tensile specimen of Type 347 stainless steel pulled to ultimate strengths of from 85,000 to 87,000 psi with all failures in the parent metal

An unconventional, although indicative, test which was performed on several samples which were welded with the root pass only is shown in Figs. 20 and 21. This sample was bent double on itself in the direction of a root and face bend. Although the pipe walls are virtually back to back, there is no visible evidence of cracks or fissures in the weld.

The tensile tests performed were reduced section tests machined and tested to the requirements of the same specifications as were the bend tests. Figure 22 shows photographs of such tensile specimens. At no time was there evidence of cracking or separations at the fusion lines in either the bend tests or the tensile tests. Tensile specimens of Type 347 stainless steel were pulled to ultimate strengths of from 85,000 to 87,000 psi with all failures occurring entirely in the parent metal.

Another phase of destructive testing to which numerous welded test specimens were subjected was the macro and micro examination of weld structures produced by this method. Such testing is particularly pertinent when made on welded specimens of Type 347 low tantalum, austenitic stainless steel. At least 50-

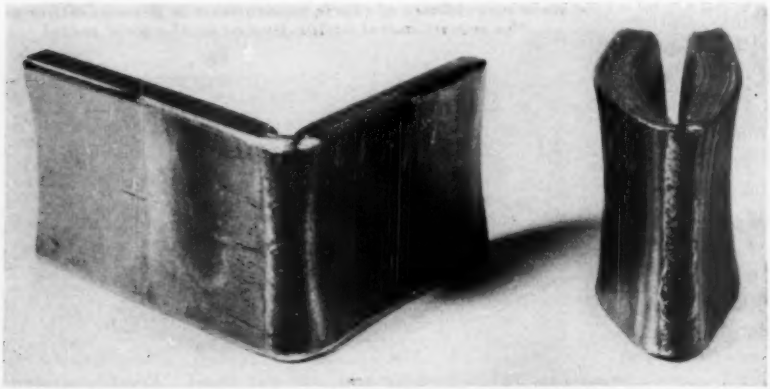


Fig. 20 Root-bend tests. Insert ring, root pass only. A severe, unconventional test of the root pass only. Note root face bent double

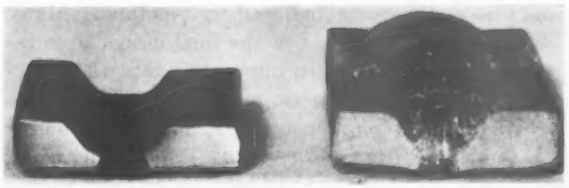


Fig. 23 The Macro section of the fused insert and the completed insert weld, show a refined dendritic structure

odd macro sections were made from Type 347 LTA specimens taken from all quadrants of pipes welded in both the horizontal fixed and vertical positions to show a structure similar to that of Fig. 23. These specimens show a refined, dendritic structure with evidence of complete fusion of the insert in its absorption into the joint. Confirming the radiographs and dyed oil penetrant checks made, the specimens showed no evidence of cracking, voids, tears or inclusions of gas, slag or tungsten in the root passes. To verify the composition of the insert (Fig. 4) filler material used on Type 347 LTA stainless steel, as well as to examine more closely the weld structure, a total of 350 metallographic examinations were made from welded joints at various magnifications from 50 to 1000 ×. Figure 24 shows a photomicrograph of the root weld structure at the fusion zone adjacent to the internal reinforcement. The metallographic examinations revealed that a slight dilution of parent metal occurred into the joint. The general microstructure appeared very similar to that produced by conventional metallic arc welding of this material except for the absence of the typical structure adjacent to the normal backing ring crevice.

Each of the 350 examinations made included ferrite determinations. The method used in these counts was the direct reading method using a microhardness tester in a field of 750 ×. By this method, the filler material

Fig. 24 Photomicrograph of the root-weld structure. Note the absence of cracks and fissures in the fusion zone at root of weld adjacent to the parent metal

Fig. 25 Ferrite distribution in the root area. × 100

of Fig. 4 yields a well-distributed ferrite count of from 4 to 7% (Figs. 25 and 26). Generally, the central areas of the root pass had a slightly higher percent of ferrite (average of 5.5%) than areas immediately adjacent to the fusion line (average of 4.3%). Dilution of the weld by the base metal is no more pronounced by using this method than with conventional methods. In fact, because evidence indicates that the dilution is distributed evenly through most of the weld, the net effect on dilution appears to be less than many areas of conventionally welded joints with backing rings.

Further, the metallographic work on these specimens revealed, first, that the results are independent of the differences in operator technique; second, the internal weld surface is free of crevices; and, third, the percentage of ferrite does not undergo any noticeable change with the addition of metallic arc weld deposits over deposits made by the insert method of root pass welding.

Radiographic Standards

The development of radiographic standards for the purpose of evaluating the quality of root passes deposited by the insert method revealed significant characteristics of the method. The first problem in obtaining these standards was to weld pipe joints with intentional defects such as burn-through, lack of complete fusion of the insert, crater cracks, porosity and inclusions. Attempts to cause a burn-through at the ampere settings noted in the above procedure description were entirely unsuccessful although operators concentrated the arc over one spot for as long as two minutes. Only by boosting the ampere capacity was

Specimen	Description	Percent Ferrite										Fusion average	Control averages
		1	2	3	4	5	6	7	8	9	10		
159-1	8" pipe	5.0	3.1		4.4	6.3	2.5	3.8	4.8	7.0	5.4	4.7	6.2
159-2	All clock	4.2	3.5		7.9	5.1	4.0			5.0		4.9	5.0
159-3	positions	5.0	4.5	3.4		7.0		3.0	3.8	3.8	6.5	4.4	5.1
159-4	included	3.7	5.0	2.4	3.5	7.2	6.5	3.0		5.0		4.4	5.0
159-5*		7.8	4.5	4.5		7.2	3.0	3.8	5.7	4.2		5.2	4.2
159-6*	Double star,	5.0	5.0	7.1		4.2	3.0	6.0	4.5	6.2		4.9	6.2
159-7*	nos. are	4.3	2.7		7.1	5.3		4.2	6.5	7.0	4.1	5.0	5.5
159-8*	complete	6.0	4.3	4.8		5.2	2.9	3.7		4.5	5.2	4.4	4.8
159-9*	weld	4.7	4.7	3.6		5.3	4.1	4.4		4.7	5.4	4.4	5.1
159-10*	Single star,	4.3	3.7		4.9	5.7	4.8	4.2		5.2	7.0	4.6	6.1
159-11**	welds incomplete	4.7	4.3		5.1	6.0	4.3	4.8		5.2	5.4	4.8	5.3
159-12**	No star, insert	5.5		3.4	4.9	8.0	4.1		4.9	3.1	5.9	5.1	4.5
159-13**	weld only	4.7	3.4		4.9	8.0	3.7	4.2	6.3	5.1	7.8	5.0	6.4
159-14**		4.7	3.9	3.0	5.2	5.7	4.1		6.0	4.7	8.0	4.6	6.3
159-15**		4.6	4.1	4.9	5.7	6.6	3.0	3.8	5.2	5.8	5.2	4.7	5.5
159-16	Macros retreated	7.0		3.9	5.1	4.6		4.2	6.0	5.0	4.7	5.1	4.8
159-17	as micros	5.1	3.4		4.2	5.1	5.1		7.0	4.8	7.0	4.9	5.9
159-18	8" pipe	6.2	3.0	4.4		5.0	4.4		4.9	3.1	5.7	4.6	4.4
159-19	Insert weld	4.9	4.2		5.7	6.7		3.0	4.7	6.2	4.5	4.8	5.3
159-20	only	7.0		4.3	5.0	4.9		4.2	6.1	4.4	5.9	5.2	5.1
159-21	Macros re-	6.1		3.5	5.5	4.7	2.9	3.3		5.0	5.4	4.3	5.2
159-22	examined as	4.9	4.4		5.7	4.6	4.1			7.1	5.7	4.7	6.4
159-23	micros	4.9	3.6	3.8	5.2	6.3		4.1	4.6	5.2	4.7	4.6	4.9
159-24	6" pipe	5.0		2.3	5.4	6.4		4.2	4.9	7.0	4.9	4.7	5.9
	Complete weld												
159-25		4.2		3.6	6.1	5.4	3.9		5.2		5.0	4.7	5.0
159-26	4" pipe	4.2		4.2	5.1	6.2		3.8	4.9		5.5	4.7	5.5
159-27	Insert weld	6.3		3.2	4.9	5.6	4.2		5.2	4.6	5.9	4.9	5.1
159-28	only	4.9	4.4		5.5	5.1		4.0	6.4	5.7	5.9	5.0	5.8
159-29		5.9	3.4	2.9	6.2	4.4		4.0	5.4	8.0	5.2	4.6	6.6
159-30		5.2		3.9	5.1	5.9	2.7		4.1		6.0	4.4	6.0
159-31	2" pipe	4.8		3.1	4.4	6.0	4.2	3.6	4.9	4.9	5.5	4.4	5.2
159-32		7.1	3.9	2.1	4.9	5.6	4.1	4.6	5.7	8.3	5.9	4.7	7.1
159-33		5.9	4.2		8.0	6.2		3.9	5.4		5.1	5.6	5.1
159-34	6" pipe	7.1		3.7	5.5	5.5		4.1	5.2	6.9		5.1	6.9
159-35		4.9	3.0		5.2	6.1		4.4	4.8		5.7	4.7	5.7
159-36	Complete	6.2	3.4		5.1	5.4		4.1	4.6	6.1	4.5	4.8	5.3
159-37	weld	4.3	4.3		5.5	5.1		4.2	6.1		6.2	4.9	6.2
159-38		5.0		4.7	4.7	8.1		4.9	5.2		6.0	5.4	6.0
159-39		5.6		3.9	4.7	5.2			5.1	7.1	4.3	4.9	5.7
159-40		4.8	3.7		5.2	5.2		2.9	6.5		6.4	4.7	6.4
159-41		6.1		3.3	4.9	6.2		5.4	8.1	6.2	7.4	5.6	6.8
Average per read sta.		5.2	3.8	3.7	5.3	5.8	3.9	4.0	5.4	5.4	5.6	4.3	5.5

Fig. 26 Ferrite data chart for the root pass areas

it possible to cause a burn-through. Figure 27 shows the repair made on such a burn-through. By moving away from the molten pool at various stages of heating, varying degrees of insert fusion were obtained as noted in Fig. 13. Such a defect is recognizable by the well-defined, straight edges of the insert and the whiteness of the film. The white of such areas indicates that the extreme internal surface area of the insert was not fused.

Insert Development

The configuration and size of the insert was developed by the "cut and try" method. Many variations of the final design were incorporated into weld joints with varying degrees of success. The desire for a preplaced filler material stemmed from the necessity of enforcing a deposition of added filler material to control the weld composition. This latter point is particularly important to achieve when welding the highly austenitic stainless steel alloys in order to achieve an optimum distribution of ferrite throughout the weld. Furthermore, previous weld development work with the various methods of pipe welding without backing rings indicated a highly sensitive condition, in butting parent metal and fusing narrow root faces, which was difficult to control from the burn-through standpoint. The equivalent of the stability gained from backing ring metal behind the joint had to be achieved in a new method. It was for these reasons that a suitable preplaced filler material was sought.

The insert wire is rolled, in simple rolling dies, to the approximate diameter of the pipe ID and cut off to leave approximately $^1/_2$-in. overlap for trimming at joint assembly. Commercial pipe tolerances allow too much inside diameter variation to permit proper fitup to the pipe and give an acceptable butt condition in the assembled insert without a trimming operation of the overlap to obtain the fit desired.

Automatic Applications

The joint and insert design noted in this procedure are being welded with an automatic drive of the torch head around a pipe in the horizontal fixed and vertical fixed positions and along a plate butt in the downhand, vertical and overhead positions. Development of automatic techniques and the driving mechanisms for

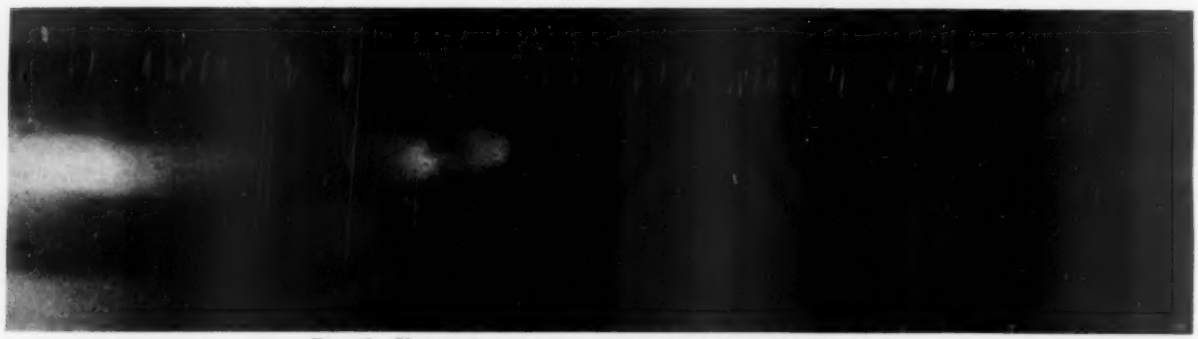


Fig. 27 X-ray of repair on a burn-through in the root pass

production applications is actively underway based on the successful "bread board" driving mechanisms built for use in the laboratory.

CONCLUSIONS

The insert method of root pass welding is considered to be a practical and simple method which provides an optimum control over the application of heat and the final constituents and structure of the deposited weld. Although joints of premium quality require significant expenditures of shielding and purging gas, these costs are a nominal price to pay for the elimination of the need for backing rings as well as for the assurance of full-penetration welds without the danger of burn-through. A projected phase of future development includes the adaptation of the method using less-expensive dry nitrogen for a purging gas behind the joint.

Statistics compiled from the welding and testing of the numerous development and production joints made using this technique indicate definitely that consistency of quality of weld structure is an assured characteristic of this method if the procedures outlined here are followed. Experience with this method will lead to the realization that all of the necessary and desirable requirements for a method of welding pipe without backing rings may be met by the application of these techniques. The method satisfies all of the following:

1. A machinable joint preparation within the reach of normal machine shop practices and compatible with the tolerances on wall thickness and circularity of pipe produced to commercial standards.
2. The weld deposit composition is controlled.
3. The introduction of fixed amounts of filler material is assured for each increment of weld.
4. The fit-up of a joint allows discrepancies in dimensions without inhibiting the quality or appearance of the finished joint.
5. This method allows for a minimum of operator dexterity and an optimum of control over the application of welding heat.
6. The method gives equivalent results in all positions of welding.
7. The resultant internal surface of the joint is smooth, well-blended to the adjacent pipe wall and free of crevices or cracks. These characteristics prevent entrapment of fluids, materially lessen flow turbulence and improve the over-all corrosion resistance of the joint.
8. Normal inspection procedures reveal all inconsistencies in technique as well as all inherent defects.
9. Destructive tests of all types and degrees of examination prove equivalent or superior to the same tests performed on materials joined by the more conventional methods of welding.
10. Operator training is limited to that normally required of an inert-gas-shielded tungsten-arc welder.
11. The method is readily adaptable to automatic welding with no loss of the quality advantages gained in manual application.

ACKNOWLEDGMENT

The authors wish to express their gratitude to the Electric Boat Division of the General Dynamics Corp. for permission to present this article. Acknowledgment is given to H. B. King, Supervisor, and the Welding Department at Electric Boat for their valuable contributions to the work reported in this article.

Current Welding Literature

(*Continued from page 669*)

L. F. Defize. Can. Mach., vol. 65, no. 3 (Mar. 1954,) pp. 187–190, 192, 194, 196.

Welding, Electric Arc. Plain Tips on Plain Steels, L. F. Spencer. Welding Engr., vol. 39, no. 3 (Mar. 1954), pp. 38–42.

Welding Engineering, B. E. Rossi. McGraw-Hill Book Co., N. Y., (1953), 786 pp., $8.00.

Welding in South Africa, F. J. A. van Reenen. Brit. Welding J., vol. 1, no. 3 (Mar. 1954), p. 101–105.

Welding Machines. G. E. C. Precision Spot Welding Machine with Electronic Control. Machy. (Lond.), vol. 84, no. 2157 (Mar. 19, 1954), pp. 614–615.

Welding Machines. Spot Welder Retooled for Greater Production, W. E. Cain. Tool Engr., vol. 32, no. 2 (Feb. 1954), pp. 75–76.

Welding Machines. Semiautomatic Welder Adapted to Magnetic Flux, R. A. Hand. Oil & Gas J., vol. 52, no. 39 (Feb. 1, 1954), pp. 88–89.

Welding Pressure. How to Use Hot Pressure Welding. Industry & Welding, vol. 27, no. 1 (Jan. 1954), pp. 50–52, 55–57.

Welding Pressure. Investigations on Pressure Welding, R. F. Tylecote. Brit. Welding J., vol. 1, no. 3 (Mar. 1954), pp. 117–135.

Welds Stress Relief. Heat-Treatments of Welded Structures for Relief of Residual Stresses With Particular Reference to Type 347 Stainless-Steel Weldments, W. L. Fleischmann. Am. Soc. Mech. Engrs.—Trans., vol. 76, no. 4 (May 1954), pp. 645–648.

Welds Testing. Effect of Surface Conditions on Porosity and Mechanical Properties of Weld Metal, K. Winterton. Welding & Metal Fabrication, vol. 22, no. 3 (Mar. 1954), pp. 101–104.

Welds Testing. Proposal for Classification of Weldability Tests, H. Granjon. Brit. Welding, J., vol. 1, no. 3 (Mar. 1954), pp. 105–115.

Welds, X-ray Analysis. How to Interpret Weld Radiographs. Industry & Welding, vol. 27, no. 3 (Mar. 1954), pp. 58–62, 64–66.

Welds, Stress Relief. Thermal Treatment of Weldments, A. Luthy. Welding & Metal Fabrication, vol. 22, no. 3 (Mar. 1954), pp. 108–111.

EDITORIAL PREVIEWS

Slag-Gas Shielded Welding

THE new process was formally introduced at the Buffalo Welding Show the week of May 2nd.

The new "BERNARD-ARC"* slag-gas shielded welding process, which is a manually applied semiautomatic welding process, deposits electrode metal at a rate of 10 to 40 and more pounds per hour.

The electrode is tubular in construction and a flux is contained within the cavity of the tube. As the metal part of the electrode is melted by the heat of the arc and transferred through the arc to become part of the weld metal, the flux core also melts and is also transferred through the arc to become the refining and shielding blanket of slag. Both the metallic part of the electrode and the flux transfers through the arc in a finely divided ionized state. While in this finely divided form, the flux as well as the metal part of the electrode would become highly oxidized unless shielded from the surrounding air. It is to prevent oxidation of the electrode materials while transferring through the arc that a separate gas, not a product of the flux, is used for shielding the arc column.

The new economy is not accomplished entirely by the slag-gas-shielded electrode. In fact, without the new semiautomatic welding machine and new arc welding torch the new high-speed welding process would not be possible. The new torch is unique for the reason that the welding current, the arc column shielding gas, the water which keeps the torch cool and the welding electrode all pass through the handle of the torch. With this arrangement the torch is streamlined and is easily manipulated for accurately guiding the welding operation along the seams welded. Another unique feature is that the coiled electrode is not located remotely from the welding torch as is the case with other semiautomatic welding equipment. In the present design, both the reel for holding the coiled electrode and the electrode feeding mechanism are rather rigidly attached to the handle of the arc-welding torch. With this new design the flexability of the electrode has no bearing on the maneuverability of the torch; therefore, this feature permits the use of large diameter electrodes. To provide practically effortless movement of the torch, the torch together with the coil of electrode and the electrode feeding mechanism is supported by a free-floating universally hinged boom. With this arrangement, the weight of the torch is only several ounces in the hand of the operator. In that the movement of the free-floating boom is made through precision ball bearings the welding torch has effortless unrestricted lateral movement over a large floor area.

With the exception of guiding the torch along the seam being welded and controlling the rate at which the torch is moved along the seam for producing the desired size of weld, the welding operation with the new equipment is entirely automatic. This is an outstanding improvement over the manually applied flux-coated electrode process which requires that the electrode be manually fed exactly at the proper rate for maintaining the arc voltage.

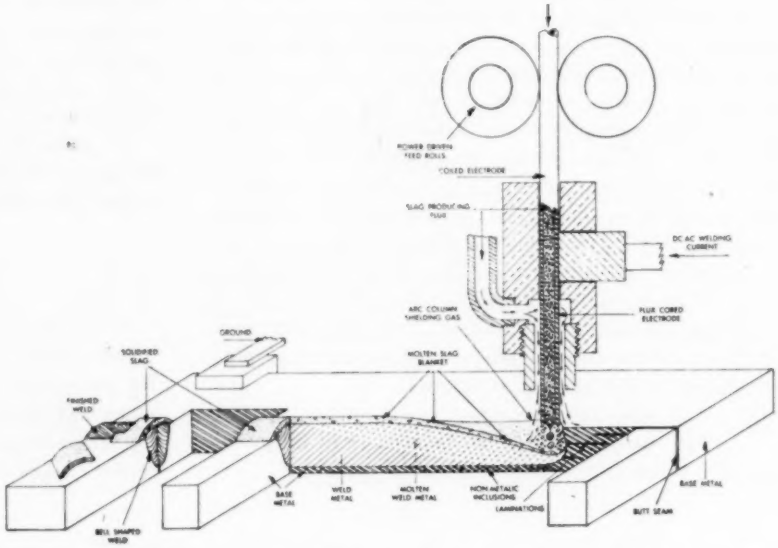


Fig. 1 Schematic diagram of "Bernard-Arc" slag-gas-shielded arc-welding process (patents pending)

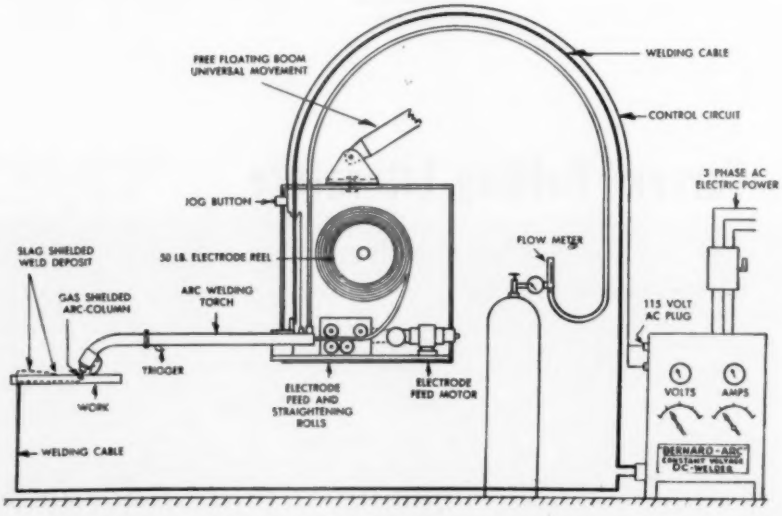


Fig. 2 Schematic diagram of "Bernard-Arc" welding torch and allied equipment

*"BERNARD-ARC" is a trade-mark of Bernard Welding Equipment Co.

Magnesium Shell Racks—A Lightweight Job for Heliarc Welding

A CURRENT application of that wonder metal, magnesium, is its use in the fabrication of shell-loading racks, commonly called "shot-trays." To guard against possible sparks while being filled with explosives, mortar shells had formerly been held in position by wooden racks. Overflowing powder became embedded in the wood grain, necessitating a thorough scrubbing which in turn produced deepened grains, for further penetration. Magnesium racks serve more effectively by being easier to handle and to clean, and are also sparkless.

Constructed of Dow type-FS magnesium alloy, a number of these racks have been fabricated in the welding shop of the Modern Light Metals Co. in Coloma, Mich. An entire unit, requiring approximately 40 ft of welds, can be welded in $1^1/_2$ hr, with a Heliarc HW-10 water-cooled torch, using argon as the shielding gas.

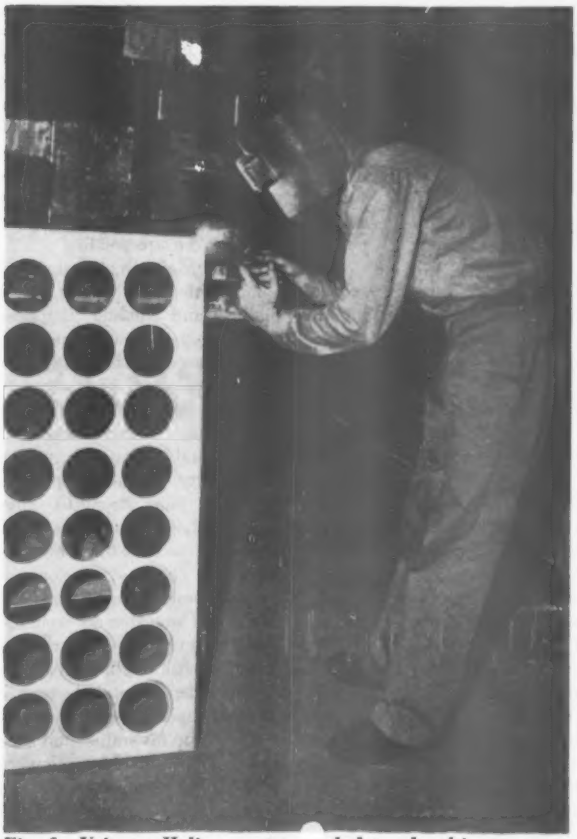


Fig. 1 Using a Heliarc water-cooled torch, this operator is tack welding the inside joint of a magnesium side angle and base plate, during the fabrication of lightweight, sparkless "shot-trays"

Fig. 2 A continuous one-pass weld is being made along the outside edges of the base section, sealing the joints which had been tack welded in a previous operation. No finishing is required on these smooth welds

The "shot-trays" are made in two sections, a base and a removable lid, both units having a series of symmetrical holes punched through them to support the shells. The empty shells are placed in the holes of the base and are held firmly by the lid when it is fitted and clamped around them.

The base section is $^1/_4$-in. plate, with a $35^7/_8$ by $45^7/_8$ in. surface. First holes are punched out. A number of tack welds join $2^1/_4$- by $1^1/_4$- by $^3/_{16}$-in. angles to the bottom edges of the base plate, as in Fig. 1, to serve as a foundation. Three crosspieces, $^1/_4$ by $2^1/_4$ in., are tack welded on the underside, 15 in. apart, providing a more rigid support to the unit. A continuous single-pass weld is then made along the outside edges to seal the corner joints between the side angles and the base plate. This operation is being performed in Fig. 2. To support the lid at the desired height, four pieces of 2 by 2 by $^3/_{16}$ in. angles, $6^3/_4$ in. in length, are fillet welded in an upright position to the corners of the now completed base. Fabrication of the top section, or lid, follows the same procedure.

the AMERICAN WELDING SOCIETY

activities • related events

Subscription Rates

Effective September 1, 1954 the subscription rates to the *Welding Journal* will be increased from $6.00 to $7.00 for domestic subscription and $7.50 to $8.50 for foreign subscription. Price of single copies remains the same at $1.00 per copy to nonmembers and 75¢ per copy to members.

Tentative Specifications

Tentative Specifications for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes. Here, for the first time, are specifications covering stainless steel filler metals for use with the inert-gas metal-arc process. These latest specifications, issued jointly by the ASTM and the AWS (ASTM Designation A371; AWS Designation A5.9), include corrosion-resisting chromium and chromium-nickel steel welding rods and bare electrodes. The rods are for use with the atomic hydrogen and inert-gas metal-arc (nonconsumable electrode) welding processes. The bare electrodes are used with the submerged arc and inert-gas metal-arc (consumable electrodes) welding processes.

Thirteen classifications of filler metal are established by these specifications, including all the commonly used materials. This involves, among others, the 18–8, 25–12 and 25–20 chromium-nickel steels as well as the 5, 12 and 16% straight chromium steels.

A table gives the chemical analysis of the different classifications for verifying conformity of a given filler metal to the standard requirements. Standard sizes and lengths and packaging requirements are also provided.

An Appendix is included as an aid to users in selecting the most suitable filler metal for their needs. It provides information on the use of each classification for joining different base metals with the different welding processes.

Copies of the Specifications can be obtained at 25 cents each from the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa., or the American Welding Society, 33 W. 39th St., New York 18, N. Y.

Technical Sessions Contribute to Success of 1954 AWS National Spring Meeting

The technical program of the 1954 National Spring Meeting in Buffalo was one of the most successful ever sponsored by the American Welding Society. It was divided into 14 sessions and featured the presentation of 41 papers. These papers skillfully prepared and presented, covered many topics and problems of wide and timely interest to the welding industry, and reflected the latest technical developments concerning welding processes and techniques, equipment, weldability of metals and training.

The technical papers sessions got off to an excellent start on Tuesday afternoon, May 4th, with papers on "weldability" and "inert arc welding." The first of these two sessions dealt with physical properties and other characteristics of arc welds. The second was devoted to an explanation of some of the factors which must be considered when making use of the shielded-inert-gas metal-arc welding process.

Morning and afternoon sessions were held on Wednesday, May 5th. Papers on "resistance welding," "stainless steel" and "surfacing and metallizing" were given during the morning; the afternoon was taken up with papers on "resistance welding," "pressure vessels and penstocks" and "supervisory personnel training."

The resistance welding papers covered such varied topics as the spot welding of aluminum, flash welding of copper to aluminum tubing, series spot welding of auto-body steel and an interpretation of standards for RWMA type A-1 transformers. Ferrite in type 347 stainless steel deposits and the production of welded stainless steel pipe were the subjects discussed at the stainless steel session. The surfacing and metallizing papers included semiautomatic applications, fatigue tests and hardness and abrasion resistance properties. Design features, welding procedures and fabrication problems were outlined and explained by the authors at the pressure vessels and penstocks session. Among the many phases of supervisory personnel training, those which received careful attention were post high-school technical education, extension courses in welding metallurgy, welding technology in an industrial institute, and the training of resistance welding supervisors.

"Titanium," "Structural" and "Process and Equipment" were the titles of the three sessions held on Thursday morning, May 6th. The titanium papers covered such phenomena as the embrittlement of heat-affected zones by air contamination and the effect of alloying elements on the weld deposits; a discussion of high-temperature brazing was also presented. The special problems encountered in the welding of bridge structures and the calculation of welded joints constituted the subject matter for the structural session. As part of the process and equipment session, there were papers on manually guided submerged arc welding and on power sources for d-c arc welding.

Friday morning, May 7th, was devoted to sessions on "nonferrous" metals, "piping and tubing" and welding "applications." The brazing of molybdenum for high temperature service, the welding of 90/10 copper nickel alloy, and adhesive bonding were discussed at the first of these three sessions. Under the general heading of piping and tubing, the authors covered the validity of radiography in predicting pipeline joint strengths, consumable insert method of root pass welding and procedure for welding tubes in heat exchangers. The last session included papers on practical considerations in the application of tungsten arc welding, industrial research and procedure control as applied to automatic welding processes, and the use of powdered metal electrodes.

The technical papers sessions, as indicated by the very favorable audience reaction, were unquestionably a complete success. Besides the excellent job done by the authors and the discussers of the various papers there was an invaluable contribution made by the unusually capable presiding officers and session supervisors.

THE SECOND AWS Welding Show and Spring Meeting

BUFFALO MAY '54

AWS President Fred L. Plummer, in symbolic ceremony, cuts Entrance Chain to the 1954 Welding Show with the oxy-acetylene flame

Registration areas at Show (top—Auditorium) and at Technical Meeting (bottom—Statler Hotel) were busy spots all times

7683 REGISTERED ATTENDANCE

at the

All-Welding Show!

If you were at Buffalo, May 4th through 7th, you know that the 2nd AWS Welding and Allied Industry Exposition and the 1954 National Spring Technical Meeting were a tremendous success. If you were not, doubtlessly, you have been told about it by enthusiastic attendees. On Thursday, May 6th, 2000 persons registered between 7:00 and 9:00 P.M.! Total "clocked" attendance was 8894!

There Was Plenty to See, Hear and Do

Each day, Wednesday, Thursday and Friday, from the time the Welding Show doors opened until they closed, exhibitor salesmen and technicians were kept busy answering the questions of the thousands of visitors–the newest welding and allied processes were demonstrated. Aisles were often jammed with welding-minded buyers and prospects trying to take in the tremendous display of labor-saving, profit-making apparatus, machines and equipment; all of the latest design, with many taken right out of the research laboratory and brought to the Welding Show floor for their first appearance. Orders were taken and invaluable contacts made every day. The general comment: the finest show ever attended! Everyone wore a satisfied grin

Something new was added to this all-welding show; the big display of Buffalo Welded Products! The fabricators of the Niagara Frontier cooperatively collaborated by exhibiting welded components and products. Visitors were able to see the practical application of welding and to learn how extensively Buffalo manufacturers have adopted welding as being the modern and most economical metal joining procedure

Severa plant visits were arranged for those who wanted to see welding being done under regular shop conditions. Both the Ford Stamping Plant in Buffalo and the Bethlehem Steel Co. in Lackawanna were "plant visit hosts" to many AWS members and guests. In addition, a tour was made of the Canadian Hydro Plant in Ontario, Canada

On Tuesday evening, the Niagara Frontier Section became general host to all of the National Society at a well-attended banquet in the Statler Hotel. President Fred L. Plummer and Admiral J. F. Jelley gave keynote talks; they were followed by excellent professional entertainment and dancing for the guests

To an attentive banquet audience, President Fred L. Plummer delivered a stirring address which has since received widespread publicity. In his talk on "Welding in Today's and Tomorrow's Worlds" he pointed out the tremendous developments which will take place in the next quarter century and which will require production expansions beyond our present imagination, assuring a bright future for welding

Allen Clark, President of the Canadian Welding Society, AWS President Fred L. Plummer and Joe Magrath, AWS National Secretary, got together with Admiral J. F. Jelley to discuss his excellent banquet address "Builders Abroad" which covered his war experiences and the dangers of Communism to the American way of life and the objectives of the Free World

It was a busy four days at the Technical Sessions at the Hotel Statler. Each morning the Authors of Papers, the Session Chairman, Co-Chairmen and Supervisors would join at breakfast with the Meeting Sessions Chairman and the Technical Papers Committee to coordinate the day's activities so that everything would click in 1, 2, 3 fashion

An interested and large audience prevailed throughout the 14 Technical Sessions, where 41 papers covering every phase of welding and the allied processes were delivered. Over 1160 registrants from every state in the United States, and from Canada attended the sessions. See the Activities and Related Events department of this issue for more complete details on the various papers

No AWS Convention would be complete without the Ladies. Their programs comprised a "Tea" at the Statler, a tour of Niagara Falls with dinner in the skyroom of the Hotel General Brock, overlooking the falls at night, a "rummage" Department Store tour and optional tours of Buffalo radio and TV stations

While the Ladies were engaged in their activities, the "working halves" took every opportunity available to crowd in program features. Among this were manual and automatic welding procedures for making Ford, Mercury and Lincoln auto parts

Lack of space makes it impossible to name all who came to Buffalo. But, here are some folks, namely: R. M. Gooderham, Director, Canadian Welding Bureau, and AWS Officers, namely: J. H. Humberstone, 1st Vice-President, C. I. MacGuffie, Chairman, Exposition Committee, J. J. Chyle, 2nd Vice-President and C. E. Jackson, District Director

On Thursday, the AWS Board of Directors held an all-day meeting, treating with many important Society activities, hearing Standing and Special Committees reports, receiving the counsel and recommendations of the District Directors and seeking solutions to various problems which are continually placed before them for decision

On Friday, the Manufacturers Committee met, reviewed the results of the Second AWS All-Welding Show, heard proposals from several cities for site for 1955 and decided that the 1955 AWS Welding Show will take place in Kansas City, Mo.

See You in K.C.—'55!

Figure 1. Lincoln INERTARC . . . *New development in quality welding with inert gases. Current range . . . 10 to 350 amps. Can be changed over for conventional AC welding in 2 minutes.*

LINCOLN INERTARC

. . . for high quality, low-cost welding with inert gases

Simplifies Operations. With INERTARC, the arc starts whenever the electrode comes within one-half inch of the work and the arc strike button is depressed. Danger of contamination by touching the electrode to the work is eliminated. Life of electrode is prolonged by accurately timed control of inert gases and cooling water.

Speeds Welding. High responsiveness to changing arc conditions provides steady arc with maximum ease . . . maximum speed of welding without sacrifice of quality on aluminum, non-ferrous and on stainless steel fabrications when AC is specified.

New Safety for Operator. Open circuit voltage on the holder remains at zero until the "start" button is depressed. With INERTARC, there is no continuous high frequency or high voltage for arc starting or welding.

Meets Requirements of F.C.C. for non-interference with radio and TV reception.

DUAL PURPOSE WELDER — INERTARC is easily changed over to conventional AC welding with coated electrodes. Changeover takes 2 minutes.

Send for Bulletin. **Complete description and specifications of Lincoln INERTARC are in Bulletin 1329. Available by writing on your letterhead to**

DEPENDABLE PERFORMANCE AT LOW COST

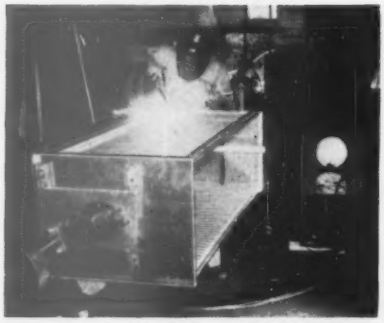


Figure 2. Speeds Fabrication *of utility cabinets from 2-S and 3-S aluminum to cut production costs.*

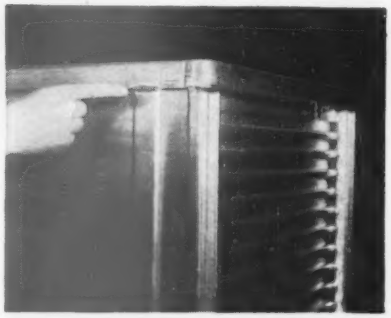


Figure 3. Improves Quality *by producing solid, smooth welds with minimum discoloration to parent metal. Photo shows bead as welded.*

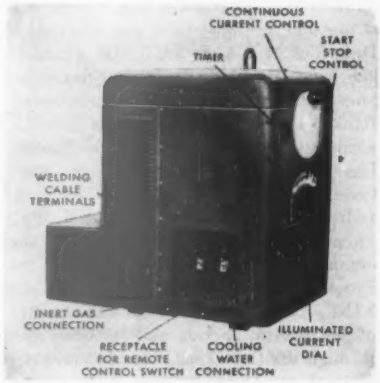


Figure 4. Simple to Install. *Connections for welding cable terminals, cooling water and inert gases are housed in recess at side of machine. Illuminated current dial indicates when welder is turned on.*

THE LINCOLN ELECTRIC COMPANY

Dept. 1906

CLEVELAND 17, OHIO

THE WORLD'S LARGEST MANUFACTURER OF ARC WELDING EQUIPMENT

Nominees for District Directors

DISTRICT NO. 1—NEW ENGLAND

H. Hugo Stahl

H. Hugo Stahl received his Bachelor Degree in 1930 in Electrical Engineering from Iowa State College, Ames, Iowa. He was a member of the following fraternities: Eta Kappa Nu (Electrical Engineering Fraternity), Tau Beta Pi (Engineering Scholastic) and Phi Kappa Phi (Scholastic).

H. Hugo Stahl

On graduating, he joined the Bell Telephone Laboratories, New York City, as a Research Engineer in telephone communication. In 1931, he obtained a leave of absence to attend the Harvard School of Business Administration and received his Degree of M.B.A. in 1933. On graduating from Harvard Business School, he joined Halsey Stuart & Co. (Investment Bankers) of New York City, as Security Analyst. In 1934 he joined the Lincoln Electric Co. and occupied various positions in production and sales, in Cleveland, Indianapolis, Cincinnati, Scranton, Pa., Philadelphia and Boston. In 1953, he organized the Stahl Equipment Co. of Brookline, Mass. He is a member of the AIEE, AWS and ASM. He was Director of the Boston Section and its Chairman through 1951 to 1952. He is currently serving as Director and Arrangement Chairman of the Boston Section.

DISTRICT NO. 6—THE CENTRAL

J. R. Stitt

J. R. (Ray) Stitt was born on Oct. 25, 1906, in Youngstown, Ohio. He was educated in the public schools in Lakewood and East Cleveland, Ohio, and graduated from Pennsylvania State University, with a B.S. in Civil Engineering in 1930.

Upon graduation, he became Field Engineer for the Austin Co. In 1933 Mr. Stitt became Sales Engineer and Representative for Una Welding, Inc., with headquarters in Newark, N. J., and in 1935 was transferred to Unaweld Manufacturing Company of Texas with office in Houston. In 1937, he returned to Austin as Field Engineer and Inspector.

J. Ray Stitt

In 1938, Mr. Stitt was asked to go to Ohio State University to organize and teach the first complete curriculum in Welding Engineering. There he served as Assistant and Associate Professor for six years, during which time 26 students graduated with the degree of Bachelor Industrial Engineering (Welding Engineering).

From 1945 to date, Mr. Stitt has been Research and Welding Engineer of The R. C. Mahon Co., Detroit, Mich. The company fabricates and erects structural steel, rolling doors, steel roof deck insulated metal wall panels, industrial equipment and a great variety of weldments, including machine bases, tanks, pressure vessels, etc.

Mr. Stitt is a member of the following engineering societies: AMERICAN WELDING SOCIETY, American Society for Metals, The Engineering Society of Detroit, Society for Non-Destructive Testing, American Society of Testing Materials, Corrosion Engineering Society, Society for Experimental Stress Analysis, Chi Epsilon and Tau Beta Pi.

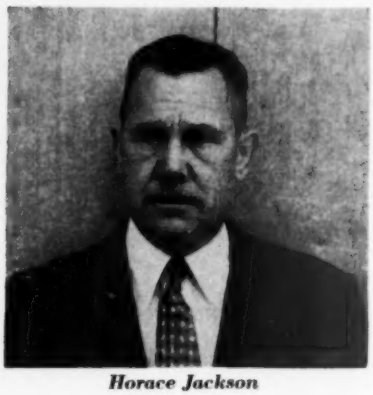
He is a registered professional engineer and in 1950 was the first engineer to become registered in Ohio in the branch of welding engineer.

In connection with the AMERICAN WELDING SOCIETY, he has been a member since 1937, has served a three-year term as Director-at-Large as well as on several National Committees. He was Chairman of the Detroit Section, 1948–49 and Secretary-Treasurer since 1949.

DISTRICT NO. 8—THE MIDWEST

Horace Jackson

Horace Jackson has been nominated by his District to become District Director of the AMERICAN WELDING SOCIETY. Mr. Jackson is Plant Superintendent of the Thompson Pipe & Steel Co. He completed his high school education in 1924 by attending night classes while serving an apprenticeship as machinist. The apprenticeship was completed in 1927. He also studied at night Mechanical Drawing, Blue Print Reading, Mathematics and Shop Practice.



Horace Jackson

Some of the positions which he held included that of Pipe Fitter for the Welder Humble Oil Refinery, Baytown, Tex., 1927–28, Machinist, C. B. & Q. Railroad, Denver, Colo., 1928–29, Arc Welder for the National Tank Co., Tulsa, Okla., until 1931. He operated his own welding and machine shop from 1932 to 1934. He joined the Thompson Pipe & Steel Co. in 1934 and in six months was promoted to Field Foreman. In 1935, he was made Field Superintendent, in 1939, Assistant Shop Superintendent, and in 1940 he became Shop Superintendent, which position he still holds.

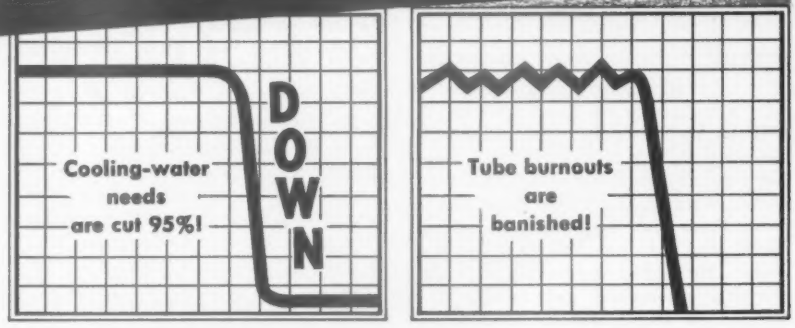
Mr. Jackson served two terms as Chairman of the Colorado Section, AMERICAN WELDING SOCIETY, and he is also a member of the Colorado Society of Engineers.

DISTRICT NO. 9—THE SOUTHWEST

James B. Davis

Welder Users: SAVE TWICE

by installing G-E TEMPERATURE-CONTROLLED IGNITRONS!



YES, you will make important savings—in cooling water, and in tube replacements. 300,000 gallons of water saved every 8-hour day—$65 at national-average water cost! That's one economy, if your plant has a large number of resistance welders.

Prevent burnouts: that's your second saving with G-E Temperature-controlled Ignitrons. Welding-tube replacements are in three figures. Every burnout you avoid, means one less new tube to buy . . . also prevents a welder outage, with its serious effects on plant production.

Get the performance facts behind these economies! Learn, too, how surfaces of Temperature-controlled Ignitrons are free from "drip" that damages panel components—another plus! Phone your G-E tube distributor today! *Tube Dept., General Electric Company, Schenectady 5, N.Y.*

New GL-6347. Size C. Will replace GL-5552/FG-235-A.

Also available are *new GL-6346,* Size B, will replace GL-5551/FG-271 . . . and *new GL-6348,* Size D, will replace GL-5553/FG-258-A.

* * *

● 14 G-E ignitrons in all—8 for welding, 6 for power rectification—mean that your tube needs will be closely met, no matter what type or size you are replacing. Superior performance is built into every G-E ignitron, to an extent where the history of the ignitron tube is written in General Electric design improvements . . . latest of these, the new Temperature-controlled Series.

GENERAL ELECTRIC

161-1B4

James Burt Davis, was born Sept. 1, 1902, in Fries, Va., and is a Registered Professional Engineer in the State of Oklahoma.

For more than thirty years Mr. Davis has been a consulting engineer and in July 1932 organized Tulsa Testing Laboratory. He has served the welding and metals industries as director of his organization since that time.

Mr. Davis was co-organizer of the Tulsa Chapter of the AMERICAN WELDING SOCIETY and has acted as secretary, director and chairman of this group. His experience, integrity and general knowledge of welding engineering have greatly contributed to the industry.

DISTRICT NO. 10—THE WESTERN

Ralph H. Smith

Ralph H. Smith, Director for District No. 10, was born in Colorado and is 54 years of age, married and has two children. Mr. Smith went to school in Colorado, Texas and New Mexico. During World War I, he was connected with the Navy. He studied construction phases of electrical engineering and became interested in Oxy-Acetylene Welding in 1920. After operating his own welding business, he joined the Oxweld Acetylene Co. as their Field Service and Sales Representative. Later he became affiliated with the Linde Air Products Co. In 1950, he established the Smith and Klemmer Co., with which organization he is a partner. This organization diverts its attention to rebuilding all makes of Tractor Rollers and Idlers, Shovel Rolers and Idlers, Mine Car Wheels, Crane Wheels and other concentric parts. This company also acts as distributors of parts for all model Caterpillar Tractors, Track Roller and Idler Bushings, Shafts, Seals and Miscellaneous parts, Mir-O-Col Hard Facing Rods, welders gloves, Stellite and H-Chrome Motor Valve Seats.

Ralph H. Smith

Nominees for District Representatives on National Nominating Committee

District No. 1 (The New England)
J. Skibo, Welding Methods Engr., Farrel-Birmingham Co., Inc., Ansonia, Conn.

District No. 2 (The Middle Eastern)
A. M. Setapen, Mgr. Engrg. Dept., Handy & Harman, 82 Fulton St., New York 38, N. Y.

District No. 3 (The North Central)
F. H. Dill, Welding Engr., American Bridge Div., U. S. Steel Corp., Ambridge, Pa.

District No. 4 (The Southeast)
J. L. Morris, Assoc. Prof., Georgia Institute of Technology, Atlanta, Ga.

District No. 5 (The East Central)
Paul Grubbs, Mfrs. Agent, 925 N. Audubon Rd., Indianapolis 1, Ind.

District No. 6 (The Central)
Robert Kemp, American Seating Co., 901 Broadway Ave., Grand Rapids, Mich.

District No. 7 (The West Central)
W. Leroy Palmer, Ind. Engr., Deere & Co., 1325 Third Ave., Moline, Ill.

District No. 8 (The Midwest)
J. W. King, Sales, Wright Welding Supply, Inc., 723 Park St., Des Moines, Iowa

District No. 9 (The Southwest)
E. M. Hotchkiss, Black, Sivalls & Bryson, Inc., 2131 Westwood, Oklahoma City, Okla.

District No. 10 (The Western)
A. H. Butler, Jr., Service Rep., Linde Air Products Co., 4542 Linden Ave., Long Beach, Calif.

District No. 11 (The Northwest)
J. H. Crumley, Welding Engr., American Pipe & Construction Co., 518 N. E. Columbia Blvd., Portland 11, Ore.

New Sustaining Member

Miller Electric Manufacturing Co., Appleton, Wis., now celebrating their 25th year in business, are manufacturers of a complete line of arc welders, both ac and dc and, in addition, manufacture gasoline-engine-driven arc welders and spot welders in various sizes.

In a-c welders, Miller builds models ranging from 100 amp output to 1500 amp output; selenium rectifier type d-c arc welders are manufactured in four sizes ranging from 200 to 600 amp, respectively; "Heliarc" welders available in three sizes; one constant voltage type selenium rectifier welder for automatic welding; a-c and d-c gasoline-engine-driven welders and combination power plants; portable and stationary spot welders.

Sustaining (A) Member Representative—Niels C. Miller

Spokane Exposition

The first Spokane Welding Exposition was held in the warehouse and display rooms of Gibson Welding Supplies, Inc., on May 21st and 22nd. Nearly a thousand people from a radius of 200 miles viewed the latest developments in welding and cutting shown by manufacturers of welding, cutting and abrasive products.

In addition to the Exposition proper which lasted for two days, one morning was devoted to a technical program. Over 200 people attended this program which featured technical papers by AWS members.

The Exposition was conducted just like a miniature version of the AWS Convention in Buffalo with individual registrations and a special program for each visitor.

Employment Service Bulletin

Position Vacant

V-311. Experimental Engineering familiar with submerged melt and inert-gas-shielded arc-welding processes. Desire man with sufficient experience to set up section of welding laboratory, select equipment for laboratory and do experimental development work for applications of above processes to result in automatic welding equipment. All applications held in strict confidence.

Services Available

A-652. Welding Foreman, Technician. Sixteen years' experience, including supervisor of manufacturing department; liaison between design engineering and manufacturing departments in new designs, methods and procedures; responsibility for conducting tests of welding methods, techniques and new equipment; instruction and testing of welders for employment and promotions; time studies and planning of assembly sequence. Full knowledge of arc welding, acetylene welding and burning, high-pressure vessel work, submerged arc welding and use of latest equipment. Familiar with low-chrome alloys, stainless steel, etc. Age 37, married. Résumé and references upon request.

A-653. Practical resistance welding man capable of maintaining and supervising maintenance of spot welders, including electronic controls. Will also work with operators, checking set-ups and instructing in proper techniques. Would consider welding engineer with some application experience. Salary open.

Remember the trade marks "tt" and "TUBE-TURN" are applicable only to products of TUBE TURNS.

Engineered for tough service

TUBE-TURN CONCENTRIC REDUCERS provide a gentle transition from large to small diameters with strong knuckle contours. They exceed the pipe itself in bursting strength and have fatigue strength equal to that of the joining butt weld.

This extra quality at no extra cost is typical of the entire Tube Turns' line. You can specify TUBE-TURN Welding Fittings and Flanges and ***know*** that you will get the *exact* answer to your specific piping problem. This leading line includes more than 4000 items in all piping materials, schedules and sizes to match *your* design . . . available promptly through your nearby Tube Turns' Distributor.

The Leading Manufacturer of Welding Fittings and Flanges

TUBE TURNS

LOUISVILLE 1, KENTUCKY

A Division of National Cylinder Gas Company

DISTRICT OFFICES: New York • Philadelphia • Pittsburgh • Cleveland • Chicago • Denver • Los Angeles
San Francisco • Seattle • Atlanta • Tulsa • Houston • Dallas • Midland, Texas

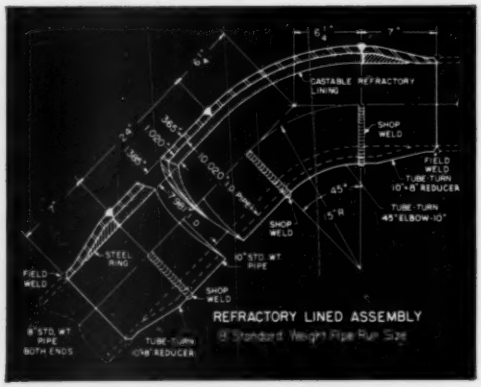
YOUR PIPING PROBLEM?

Here's service to help you...

TUBE TURNS' Engineering Service Division is staffed with men of wide experience to help solve your piping problems. Typical of many they encounter is this:

The general practice in handling highly abrasive materials in piping is to use heavy wall carbon steel elbows for directional changes, and replace these as they wear out. Recently, a new pipe lining . . . a zirconia-corundum refractory . . . was introduced with exceptional wear-resistant properties. This offers a highly satisfactory solution to the abrasion problem. The sketch shows how this lining can be applied to a 45° elbow by combining with two reducers.

This application is practical for piping of 4" through 12" diameter. Minimum thickness for casting of refractory is about one inch. It should be confined to mild pressure-temperature conditions. Additional details are available from Tube Turns' Engineering Service Division.



Design of 45° directional change with refractory-lined elbow.

YOUR SIZE: These ½-inch and 42-inch TUBE-TURN Welding Elbows are the extremes in the range of diameters available out of stock in carbon steel. Tube Turns' complete line of more than 4000 items includes fittings and flanges in carbon steels, stainless steels, chrome-moly steels, copper, aluminum, brass, monel metal, nickel and wrought iron.

YOUR SOURCE: The nearby Tube Turns' Distributor provides prompt delivery of TUBE-TURN Welding Fittings and Flanges to meet your needs exactly. He acts as your warehouse. He cuts your purchasing red-tape and time. He is backed up by the entire Tube Turns' organization.

DISTRICT OFFICES

New York	San Francisco
Philadelphia	Seattle
Cleveland	Atlanta
Chicago	Tulsa
Denver	Houston
Los Angeles	Dallas
Midland, Texas	

"tt" and "TUBE-TURN" Reg. U.S. Pat. Off.

TUBE TURNS, Dept. O-4
224 East Broadway, Louisville 1, Kentucky

Please send free copy of booklet on Stainless Steel Piping.

Company Name _____

Company Address _____

City _____ *Zone* ____ *State* _____

Your Name _____

Position _____

TUBE TURNS

A DIVISION OF NATIONAL CYLINDER GAS COMPANY
LOUISVILLE 1, KENTUCKY

Tentative Program

AWS National Fall Meeting

Sherman Hotel—Chicago, Ill.

November 1–5, 1954

WELDING AND CUTTING EXHIBITS AND DEMONSTRATIONS

NATIONAL METALS EXPOSITION

International Amphitheater
Chicago, Illinois

HOURS OF THE EXPOSITION

Monday, Tuesday and Wednesday—November 1, 2 and 3

12 Noon to 10:30 P. M.

Thursday and Friday, November 4 and 5——10:00 A.M. to 6:00 P.M.

Admission by special invitation or by AWS registration badge or membership card of any participating society.

MONDAY MORNING, NOVEMBER 1st

Chairman—F. L. PLUMMER, *President*, AMERICAN WELDING SOCIETY

Co-Chairman—H. C. BOARDMAN, *Chairman*, Technical Papers Committee

Louis XVI Room

10:00 A.M.—PRIZE AWARDS

10:30 A.M.—ADAMS LECTURE

The Toughness of Weldability
by WILLIAM L. WARNER, Watertown Arsenal

MONDAY AFTERNOON, NOVEMBER 1st—2:00 P.M.

Two Simultaneous Sessions

1—RESISTANCE WELDING

Ballroom

A. Flashwelding High-Strength Steels
by W. G. FASSNACHT, Bendix Aviation Corp.

B. Effect of Post Treatment on the Properties of Flash Welds
by ERNEST F. NIPPES, WARREN F. SAVAGE, GORDON GROTKE and S. M. ROBELOTTO, Rensselaer Polytechnic Institute

C. The Effects of Prestressing on the Strength Characteristics of Spot Welds in 17-7 Stainless Steels Under Cyclic Loads
by V. N. KRIVOBOK, International Nickel Co., and J. A. CHOQUET and G. WELTER, École Polytechnique

2—WELDABILITY

Assembly Room

A. The Effect of Microstructure on Notch Toughness—Part II
by JOHN H. GROSS and ROBERT D. STOUT, Lehigh University

B. Impact Testing Weld Metal and Heat-Affected Zone Simultaneously
by W. P. HATCH, JR., and C. E. HARTBOWER, Watertown Arsenal

C. Applicability of Charpy Test Data
by PETER P. PUZAK, MARTIN E. SCHUSTER and W. S. PELLINI, Naval Research Laboratory

MONDAY EVENING, NOVEMBER 1st

6:00 P.M.—President's Reception

Crystal and Louis XVI Rooms

8:00 P.M.—National Dinner

Bal Tabarin

Plant Visits

Arrangements have been made for two plant visits during the AWS National Fall Meeting which is to be held in Chicago, Nov. 1–5, 1954. The visits are scheduled on successive days so as to allow participation in both trips.

On **Wednesday morning, 9:00 A.M., November 3rd,** a tour will be made of the Hotpoint Co.'s new refrigerator manufacturing plant which is located in Cicero, Ill. This new plant, formally opened in October 1953, is designed and constructed to utilize the most modern equipment and manufacturing procedures. The plant occupies about one million square feet of floor space and utilizes a main assembly conveyor line 7000 ft long. This modern innovation of plant layout minimizes the materials handling problem by having the assembly line go directly into the component parts department in contrast with the usual procedure of having the component parts brought to the assembly line. During the tour several welding and brazing operations will be seen including many modern, completely automatic resistance welders, inert gas welding, oxy-acetylene welding, etc., and the latest scientific equipment and instruments used to reduce the moisture content in the refrigeration equipment to as low a point as it is humanly possible to attain. In addition, leak detectors will be seen in use which can detect leaks so small that it would take 200 years for 1 oz. of the refrigerant liquid to leak out.

On **Thursday morning, 9:00 A.M., November 4th,** a tour will be made of the Whiting Refinery and Research Laboratories of the Standard Oil Company of Indiana. The refinery proper, covering 1100 acres, is one of the largest refineries equipped to make a complete line of petroleum products. It processes an annual average of 208,000 bbl of crude oil per day with a daily gasoline output of 3,700,000 gal. In addition to gasoline, the refinery produces very sizable amounts of fuel oil (domestic and industrial), asphalt, greases, candles, insecticides, rust preventives and other chemicals. After touring the most interesting portions of the refinery, including the Welding Shop, the group will be taken through those portions of the Research Laboratory and Administration and Engineering Building which will be of interest to the AWS visitors.

TUESDAY MORNING, NOVEMBER 2nd—9:30 A.M.

Three Simultaneous Sessions

3—WELDABILITY

Assembly Room

A. Isothermal Studies on Weld-Metal Microcracking in Mild Steel
by ALAN E. FLANIGAN and Z. P. SAPERSTEIN, University of California

B. Crack-Starter Tests of Ship Fracture and Project Steels
by P. P. PUZAK, MARTIN E. SCHUSTER and W. S. PELLINI, Naval Research Laboratory

C. Continuous Cooling Transformation Characteristics of Three Types of Weld Metal
by E. F. NIPPES and E. C. NELSON, Rensselaer Polytechnic Institute

4—RESISTANCE WELDING

Crystal Room

A. Spot Welding Aluminum with Single-Phase Equipment
by J. W. KEHOE and D. R. McCUTCHEON, Westinghouse Electric Corp.

B. Seam Welding Low-Carbon Steel
by M. L. BEGEMAN and GENE C. WALKER, University of Texas

C. Automatic Percussion Welding
by A. L. QUINLAN, Western Electric Co.

5—SHIELDED ARC WELDING

Louis XVI Room

A. Recent Developments in Contact Electrodes
by D. L. MATHIAS, Arcrods Corp.

B. Electrodes with Powdered Metal Coatings, A Progress Report
by JERRY HINKEL, The Lincoln Electric Co.

C. Metallic Rectifiers for Arc Welders
by G. K. WILLECKE, Miller Electric Mfg. Co.

TUESDAY AFTERNOON, NOVEMBER 2nd—2:00 P.M.

Section Officers Meeting

Crystal Room

TUESDAY AFTERNOON, NOVEMBER 2nd—2:00 P.M.

Two Simultaneous Sessions

6—WELDABILITY

Assembly Room

A. Arc Welding Embrittlement of Powder Metals
by ALBERT SILL, JR., and C. C. MATHIAS, Sperry Corp.

B. Weldability of Wrought, High-Alloy Materials
by R. P. CULBERTSON, Haynes Stellite Co.

7—SURFACING

Louis XVI Room

A. High Nickel Alloy Overlays on Ferrous Metals
by GEORGE R. PEASE, H. B. BOTT and H. C. WAUGH, International Nickel Co.

B. The Inert Gas Metal Arc Overlay Process
by C. R. FELMLEY, Air Reduction Sales Co., Inc.

C. Automatic Hard Surfacing in the Mining and Construction Industries
by I. R. BARTTER, Automatic Welding Co.

WEDNESDAY MORNING, NOVEMBER 3rd—9:30 A.M.

Three Simultaneous Sessions

8—AIRCRAFT AND ROCKETRY

Crystal Room

A. Production of High-Strength Aluminum Alloy Rocket Motor Tubing by Means of an Induction Weld Tube Mill
by W. S. TENNER and H. C. WHEELER, U. S. Naval Ordnance Test Station

B. Metallurgical Aspect of Welding Precipitation Hardening Stainless Steels
by C. W. FUNK and M. J. GRANGER, Aerojet-General Corp.

C. The Macro Etch System of Evaluating Quality of Resistance Welding
by D. O. SAMUELSON and F. G. HARKINS, Solar Aircraft Co.

9—TITANIUM, ZIRCONIUM AND MOLYBDENUM

Louis XVI Room

A. Notch Toughness of Weld Deposits in Titanium Plate
by D. M. DALEY, JR., and C. E. HARTBOWER, Watertown Arsenal

B. The Welding of Zirconium
by RALPH V. HILKERT and HAROLD H. HOLLENBECK, Titanium Alloy Manufacturing Division, National Lead Co.

C. The Influence of Oxygen on the Joining of Molybdenum
by TIMOTHY G. PERRY, H. STEPHEN SPACIL and JOHN WULFF, Massachusetts Institute of Technology

10—INERT ARC WELDING

Assembly Room

A. New Techniques in Inert-Gas-Shielded Metal-Arc Welding
by R. W. TUTHILL, General Electric Co.

B. Inert Gas Welding of Stator Packs
by F. J. PILIA, Linde Air Products Co.

C. A Production Application of Inert-Gas-Shielded Metal-Arc Welding of Mild Steel
by JOHN L. LANG, Lukenweld Division of Lukens Steel Co.

WEDNESDAY AFTERNOON, NOVEMBER 3rd—2:00 P.M.

Three Simultaneous Sessions

11—PRESSURE VESSELS AND PIPING

Assembly Room

A. The Plastic Fatigue Behavior of High-Strength Pressure Vessel Steels
by JOHN H. GROSS, and ROBERT D. STOUT, Lehigh University

B. Further Studies of the Biaxial Fatigue Properties of Pressure Vessel Steels
by C. E. BOWMAN and T. J. DOLAN, Department of Theoretical and Applied Mechanics, University of Illinois

C. Automatic Tungsten-Inert-Arc Welding of Pipes in Position, Without the Use of Backing Rings
by L. C. McNUTT, Benjamin F. Shaw Co.

12—BRAZING

Crystal Room

A. Silver Brazing of Refractory Metals
by C. H. CHATFIELD, Handy & Harman

B. Filler-Metal Strengths in Brazed Copper Joints
by W. H. MUNSE and D. C. CRAWFORD, University of Illinois

C. Investigation of the Factors Determining the Tensile Strength of the Brazed Joint
by NIKOLAJS BREDZS, Armour Research Foundation of Illinois Institute of Technology

13—SYMPOSIUM ON FUSED METALLIZED COATINGS

(Sponsored by AWS Committee on Metallizing)

Louis XVI Room

A. Fundamentals of Fused Metallized Coatings
by BELA RONAY, U. S. Nava Engineering Experimental Station

B. Practical Applications of Fused Self-fluxing Metallized Coatings
by HARVEY S. MILLER, New England Hardfacing Co.

C. Practical Applications of Fused Non-self-fluxing Metallized Coatings
by SAM TOUR, Sam Tour & Co., Inc.

WEDNESDAY EVENING, NOVEMBER 3rd

6:30 P.M.—WRC University Dinner

Emerald Room

8:00 P.M.—WRC University Conference

Crystal Room

THURSDAY MORNING, NOVEMBER 4th—10:00 A.M.

Board of Directors Meeting

Jade Room

THURSDAY MORNING, NOVEMBER 4th—9:30 A.M.

Three Simultaneous Sessions

14—AIRCRAFT

Crystal Room

A. Considerations for Fatigue in Aircraft Welding Design
by J. KOZIARSKI, Piasecki Helicopter Corp.

B. Properties of Welds in Al-Mg-Mo Alloys XK186 and XK183
by L. A. COOK and S. L. CHANNON, Kaiser Aluminum and Chemical Corp., and A. R. HARD, State College of Washington

C. High-Temperature Alloy Brazing of Thin Materials for Jet Engines
by A. S. ROSE and W. N. LEWIS, I-T-E Circuit Breaker Co.

15—DESIGN AND PRODUCTION

Assembly Room

A. Prediction of Angular Distortion Caused by One-Pass Fillet Welding
by T. KUMOSE, T. YOSHIDA, T. ABBE and H. ONOUE, Yokohama Shipyard & Engine Works, Mitsubishi Nippon Heavy-Industries, Ltd.

B. Triaxial Tensile Stresses in Arc Welded Mild Steel
by HARRY E. KENNEDY, University of California

C. Automatic Welding Builds Railroad Cars
by H. D. HOLLIS, Texas & Pacific Railway Co.

16—CUTTING

Ballroom

A. Oxygen Cutting with Iron Powder and Chemical Flux Additives
by R. L. DEILY and J. R. KIRWIN, Air Reduction Sales Co.

B. Sigma Arc Cutting
by R. S. BABCOCK, Linde Air Products Co.

C. Improved Method of Oxy-Fuel Gas Combustion
by EDWARD H. ROPER, Air Reduction Sales Co.

THURSDAY AFTERNOON, NOVEMBER 4th—2:00 P.M.

Business Meeting

Crystal Room

FRIDAY MORNING, NOVEMBER 5th—9:30 A.M.

Three Simultaneous Sessions

17—HIGH-TEMPERATURE MATERIALS

Assembly Room

A. An Investigation of the Hot Ductility of High-Temperature Alloys

by ERNEST F. NIPPES, WARREN F. SAVAGE, H. F. MASON and B. J. BASTIAN, Rensselaer Polytechnic Institute

B. Interpreting Graphitization in High-Temperature, High-Pressure Steam Piping

by H. THIELSCH, E. M. PHILLIPS and E. R. JEROME, JR., Grinnell Co., Inc.

C. The Welding of Type 347 Stainless Steel for the Higher Steam Turbine Operating Temperatures

by R. M. CURRAN and A. W. RANKIN, General Electric Co.

18—STRUCTURAL

Ballroom

A. Behavior of Welded Single Span Frames Under Combined Loading

by C. G. SCHILLING, F. W. SCHUTZ, JR., and L. S. BEEDLE, Fritz Engineering Laboratory, Lehigh University

B. Fatigue Strength of Butt Welds in Structural Steels

by L. A. HARRIS, G. E. NORDMARK and N. H. NEWMARK, Talbot Laboratory, University of Illinois

C. New Concepts in Spot X-Ray of Welded Structures

by HAROLD HOVLAND, Industrial X-Ray Engineers

19—APPLICATIONS

Old Chicago Room

A. How to Apply Semiautomatic Submerged Arc Welding

by ROBERT A. WILSON, Lincoln Electric Co.

B. Mechanized Flame Descaling, Dehydrating and Priming of Prefabricated Plate

by C. H. COWAN, Avondale Marine Ways, Inc., and J. R. KIRWIN, Air Reduction Sales Co.

C. Automatic Hardfacing with Mild Steel Electrodes and Agglomerated Alloy Fluxes

by J. S. McKEIGHAN, The Lincoln Electric Co.

LADIES' REGISTRATION

Sunday Evening, October 31 through Thursday, November 4

SUNDAY, OCTOBER 31st

Coffee Reception, 6:00–8:00 P.M.
Orchid Room, Sherman Hotel
This reception will provide an opportunity for meeting Chicago Section Officers and their wives

MONDAY, NOVEMBER 1st

Coffee Hour, 10:00 A.M.—Orchid Room
Luncheon, 12:00 noon—Kungsholm, 100 E. Ontario St.
Puppet Opera, Kungsholm Theater following luncheon

TUESDAY, NOVEMBER 2nd

Coffee Hour, 10:00 A.M.—Orchid Room
Luncheon, 12:30 P.M.—Exclusive M & M Club, Merchandise Mart Building
Escorted tour of Merchandise Mart will follow luncheon

WEDNESDAY, NOVEMBER 3rd

Coffee Hour, 10:00 A.M.—Orchid Room
Luncheon, 12:30 P.M.—Wedgewood Room, Marshall Field State St. Store
Fashion Show to be held during luncheon
Escorted tour of Marshall Field's Store following luncheon

THURSDAY, NOVEMBER 4th

Buffet Luncheon, 11:30 A.M.—Orchid Room
Theater Party, 1:30 P.M.—Palace Theater—Cinerama (or sequel)
Theater party for both men and women as long as reservations are available

AN OPPORTUNITY —is presented to all AWS Membership and Industry to secure back numbers of The Welding Journal Bound Volumes at very low cost.

Effective now, a limited supply of the following BOUND VOLUMES are available at the prices shown.

Year	Price	Year	Price
1930	$6.00	1938	$ 6.00
1931	6.00	1948	10.00
1932	6.00	1950	12.00
1933	6.00	1951	12.00
1934	6.00	1952	12.00
		1953	15.00

Foreign postage additional

Each consists of the twelve (12) issues of that year's JOURNALS, each volume attractively bound in imitation black leather covers. These are valuable additions to your engineering and welding library.

Place order now with the AMERICAN WELDING SOCIETY, 33 West 39th Street, New York 18, N. Y. Add 3% sales tax on N.Y.C. orders.

MILLER SELENIUM RECTIFIER TYPE D.C. ARC WELDERS

Performance, dependability and low maintenance unmatched by any other! Miller's patented UNITRAN, combining transformer and flux diverter, produces *pulsating* direct current; this Miller exclusive provides higher current density, transfers more metal, minimizes magnetic arc blow and "arc-outs," produces sounder, denser welds. Operators can hold a shorter arc without sticking. Variable transfer transformer gives the SR a wider range than any other D.C. welder. Polarity reversal at the flick of a switch. Specialized controls for all welding processes and "plug-in" remote controls available. Easily paralleled in any combination with other Miller SR models. Models with rated outputs (40 volts on 60% duty cycle) of 200, 300, 400 and 600 amperes.

MILLER CONSTANT POTENTIAL TYPE RECTIFIER WELDER

Model SIGMA-5 maintains stable welding conditions regardless of arc variations, an important advance in the Shielded Inert Gas Metal Arc process. Operator sets wire feeding speed on welding head and arc voltage on the SIGMA welder. After arc is struck, *Model SIGMA-5* automatically provides the amount of current needed to burn off the filler wire at the rate required to maintain a constant arc length. Five-position tap switch and vernier rheostat control. Primary contactor and control transformer furnishes 110 volt A. C. to drive welding head and 26 volt A. C. for welder control circuit. May be paralleled and/or remote controlled. 500 ampere rated output at 30 volts on 100% duty cycle.

...for Twenty-Five Years

WELDORS HAVE AGREED

"...if it's miller you know it's the finest"

MILLER HEAVY-DUTY INDUSTRIAL A.C. ARC WELDERS

Miller *100 Series* A.C. Transformer-type Welders achieve high-quality welds at maximum production speeds, together with low cost of maintenance and long welder life. Ample open circuit voltage for arc stability, minimum "arc-out" time; uses all A.C. or A.C.-D.C. electrodes including stainless steel, low hydrogen, etc. Continuous hand-cranked current control eliminates "blank spots"; optional motor-operated current control on all models permits remote control. *Models 103, 104, 105* have 80 volt open circuits; rated secondary amperes (60% duty cycle at 40 volts) are 300 400 and 500 respectively. Power factor correction at slight additional cost. *Models 107, 108, 109* have 80 and 100 volts open circuit (selective) for automatic welding applications. Rated secondary amperes (60% duty cycle at 40 volts) are 750, 1000 and 1500 respectively. All three models power factor corrected.

miller

20% PLUS Factor

An engineer-earned designator for the basically better design, high-quality components, established efficiency and longer life of Miller welders. Free, helpful literature sent upon request.

ELECTRIC MANUFACTURING COMPANY Inc. • Appleton, Wisconsin

NEWS OF THE INDUSTRY

1955 ASTE Western Industrial Exposition

The American Society of Tool Engineers has announced that its first Western Industrial Exposition will be held in Los Angeles' Shrine Auditorium and Shrine Exposition Hall, March 14th to 18th next year. Seventeen far-western chapters of ASTE are cooperating in staging the mammoth exposition.

The entire event is in recognition of the rapid growth of western industry which more than doubled its output between 1947 and 1952 alone.

The exposition will run concurrently with 1955 annual meeting of the 30,000 member national technical society. Five-day All-Industry Manufacturing and Tooling Conferences will be held on the site of the exposition under the joint sponsorship of other technical societies and trade associations.

Carbon Dioxide Plant

The Liquid Carbonic Corp. has announced that it has signed a contract to build a large new carbon dioxide plant in Houston, Tex. The new plant, which is to be located on the ship channel, will be the latest in design.

B. W. Goulding, Vice-President of the Company's Compressed Gas Division, stated that "the tremendous industrial growth in Texas has resulted in greatly increased needs and uses for carbon dioxide. With the building of this new plant, Liquid will be ready to meet these rapidly expanding carbon dioxide demands."

At present, Liquid has carbon dioxide plants in Houston and Dallas, in addition to 24 other plants strategically located throughout the country.

Weld+Ends Price Reduction

Pipe Line Development Co., Cleveland 2, Ohio, has just announced a drastic price reduction in the most popular sizes of Weld+Ends as well as a substantial reduction in all sizes. Weld+Ends is a safety welding coupling for crude oil, gas, gasoline, propane, asphalt, tar, steam, chemical process and other pipe lines.

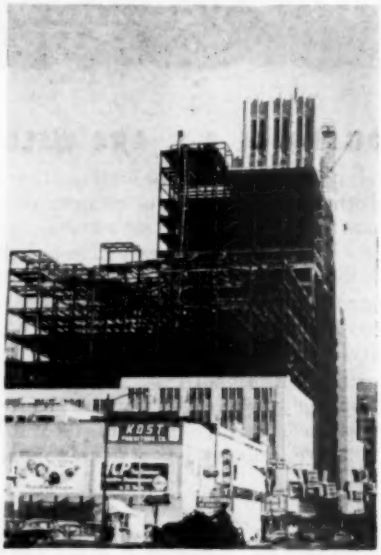
The increasing demand for the 2 and 3 in. sizes for use in maintenance plus their more efficient production by automatic machinery have resulted in savings that can now be passed on to buyers of Weld+Ends. For example, 2-in. Weld+Ends now cost 57% less and 3-in. Weld+Ends are 37½% less. Weld+Ends are also available from 4 in. (reduced 22% in price) up to 30 in. (now 5% less) in increments of 2 in.

Weld+Ends joins pipe securely so that flow can be resumed immediately at full pressure. Welding can be performed when it is convenient, when conditions are safe and while pipeline is in use—days or weeks later.

For complete price list and information on Weld+Ends, write or wire Pipe Line Development Co., 5700 Detroit Ave., Cleveland 2, Ohio.

New Welded Structures in Houston

Houston's skyline continues to be altered by the erection of welded steel building frames. Latest among these to be completed is the new Houston Club Building in the downtown area just one block west of the Gulf Building. The tower section in this structure reaches a height of 19 floors, and all beam to column connections make use of butt welds on flanges, with fillet welds on web members.



The Texas National Bank Building now being erected on a one-half block site at Main St. and Polk Ave. is likewise a welded structure that will rise some 24 stories.

Structural steel of welded design is now being fabricated for a 19-story annex to the Houston Club Building, and plans are out for bids on a new building for the Second National Bank. This latter structure is expected to involve some 7500 tons of steel, and is designed for welded fabrication and erection.

Judges Announced for Pandjiris Essay Contest

Names of judges for the Pandjiris "Positioned Welding Essay Contest" were announced at the recent AWS Welding and Allied Industry Exposition in Buffalo, N. Y. They are Howard N. Simms of Black, Sivalls & Bryson, Inc., Oklahoma City; J. J. Powers, Midvale Co., Philadelphia, and E. J. Hornack, Sunbeam Corp., Chicago.

The essays which are to describe an actual experience in the application of positioning equipment will be judged on the basis of: (1) cash value of the time saved; (2) unique nature of the experience; (3) improved product appearance; (4) cost reduction or increased production resulting. The contest closes Aug. 15, 1954. Anyone wishing further information should write the Pandjiris Weldment Co., 5151 Northrup Ave., St Louis 10, Mo.

Heavy Steel Plates Available from Stock

J. Frederic Wiese, vice-president in charge of sales, has announced that By-Products Steel Co.—a division of Lukens Steel Co—now provides fabricators with a service unique in the steel plate field through its comprehensive warehouse stock of heavy plates, ranging from ½ to 15 in. thick. These plates can be shipped full size or flame-cut within close tolerance to specified sizes and shapes.

Mr. Wiese pointed out that By-Products' shapes are cut from as-rolled mill plate to the customer's exact sketch or dimensions, and so involve only one gas-cutting charge. Current sizes and qualities carried in this extensive stock range from ¼-in. plate measuring 200 by 100 in., to 15-in. plate measuring 140 by 80 in., with tensile strengths of different specifications ranging from 55,000 to 85,000 psi.

Fabricators and designers desiring the latest information on By-Products' heavy plate stock can receive current listings in a handy reference folder. To be placed on the mailing list, write Manager, Marketing Service, Lukens Steel Co., Coatesville, Pa.

CONVEYOR DRIVE SPROCKET that was repaired by braze welding with ANACONDA-997 (Low Fuming) Bronze Rods in only 7 hours. Braze welds made with these rods are clean and strong . . . require little finishing.

SAVED: one expensive drive sprocket *plus* 53 operating days

Replacement of this fractured conveyor drive sprocket would have meant a two-month wait for delivery . . . and considerable expense to its smelting-plant owners. An inexpensive braze-weld repair had it back in operation in a matter of days. Job time was only 7 hours—4 in preparation, 3 in welding. Twenty pounds of 3/16" and 1/4" ANACONDA-997 (Low Fuming) Bronze Welding Rod were used.

Owner Walter Shanowsky, Universal Welding Co., Rochester, N. Y., reports that ANACONDA-997 (Low-Fuming) Bronze Rod gave a fast, sound weld. These rods 'tin' readily, flow freely and have good tensile strength. They melt at relatively low temperatures . . . work requires less preheating, so danger of warping or cracking is minimized.

Universal buys all its ANACONDA Welding Rods from the Welding Supply Corp. in Rochester. ANACONDA Welding Rods for almost every type of repair and production job are available from distributors throughout the United States and Canada. For latest tips on welding, write for Publication B-13 to: *The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.* 53166

braze or weld with confidence...

ANACONDA®

welding rods

New A. O. Smith Distributors

The Welding Products Division of the A. O. Smith Corp. announces the appointment of six new distributors in four states. They are: James H. Cross Co., 2765 W. 8th St., Erie, Pa.; Butler Cylinder Gas Co., McKees Rocks, Pa.; Elk Welding Supply Co., 76-19 Queens Blvd., Elmhurst, N. Y.; General Welding Supply Corp., 189 Third St., Mineola, N. Y.; Standard Electric Supply Co., 1045 N. 5th St., Milwaukee, Wis., and Midwestern Pipeline Products Co., 5005 Peachtree Rd., Chamblee, Ga.

B&W Tubular Products Division Opens District Office in Cincinnati

A new district sales office for the Tubular Products Division of the Bacock & Wilcox Co. has been opened in Cincinnati, it was announced recently by James S. Anderson, General Sales Manager of the division. The offices will be located at 2330 Victory Parkway, Cincinnati, Ohio.

The Babcock & Wilcox Co., Tubular Products Division, with manufacturing plants at Beaver Falls, Pa., and Alliance, Ohio, produces both seamless and welded stainless, alloy and carbon steel tubing and pipe for all types of pressure, mechanical and structural applications.

Henry W. Doctor of the Beaver Falls district sales office has been named District Sales Manager and will be in charge of the division's operations in Cincinnati. Russell French of the Philadelphia sales office also is being transferred to Cincinnati.

SESA Annual Meeting

The annual meeting and exhibition of the Society for Experimental Stress Analysis will be held on Sept. 21–23, 1954, at the Bellevue-Stratford Hotel in Philadelphia, Pa., in conjunction with the First International Instrument Congress and Exhibition. Frank G. Tatnall is General Chairman and Greer Ellis is Exhibits Chairman.

New Superior District Sales Office

Superior Steel Corp., Carnegie, Pa., manufacturer of Stainless, Clad Metal, Alloy, and High-Carbon Strip Steels, has announced the opening of a new district sales office at Buffalo, N. Y., located at 1212 Rand Building. Thomas C. Collins was named District Manager of the Buffalo office, which will cover the upper western New York State and Toronto-Hamilton, Canada areas.

W. M. Cowles, Vice-President in charge of sales for Superior Steel disclosed that direct mill representatives will also be assigned to the eastern portion of New York, working out of the company's New York City offices under M. E. Lowder.

Lukens Elliptical Flanged and Dished Heads

Herbert A. Ottey, manager of flanging sales, announced recently that elliptical flanged and dished heads of ASTM A-212-B Firebox steel have been added to Lukens Steel Co.'s extensive list of stock heads.

Lukens also makes a wide range of formed-to-order heads. They can be supplied beveled, machined, heat treated, sandblasted or sodium-hydride descaled.

Fabricators and designers interested in the latest information on spun and pressed heads for immediate shipment can receive Lukens' periodic mailings of current head stock lists by writing Manager, Marketing Service, Lukens Steel Co., Coatesville, Pa.

Webb Takes Over Reed

The Webb Corp. of Webb City, Mo., has been licensed to manufacture, sell and distribute the Reed line of welding fixtures and metal-forming equipment formerly built by Reed Engineering Co. of Car-

Aronson supplies the Welding Industry with the ONLY complete line of *Quality* Positioning Equipment.

POSITIONERS

UNIVERSAL BALANCE POSITIONERS for Instant manual Positioning.
27 models of BENCH TURNTABLE Automatic Welding Positioners.
PRECISION GEAR DRIVEN Magnetic Brake Positioners.
Fully Automatic MODEL 21 and 21X SERIES of Gear Driven Positioners.
HEAD and TAIL STOCK Positioners . . . Rugged . . . Precise.
Steady, Positive, Precision Rotation with TRACTRED TURNING ROLLS.
Heavy-Duty "Overload Protected" RUBBER TIRED TURNING ROLLS.
Rugged DRIVER and IDLER CARS for Turning Roll mounting.
FLOOR TURNTABLE Positioners with adjustable base.
MAGNETIC POSITIONING CLAMPS with Permanent Magnet Core.

Visit our Booth at the National Metal Exposition at Chicago, Nov. 1-5.

Aronson MACHINE CO. — WORK WORK — ARCADE, N. Y.

thage, Mo. This line will be offered by the Webb Corp. through their distributors and dealers located in all principal industrial areas.

The L. H. Knost Co. of Carthage, Mo., headed by L. H. Knost, former President of Reed Engineering Co., will be retained by Webb as consulting engineers for the design of new machines and fixtures for the plate fabricating field.

The Reed line will be manufactured by the Reed Equipment Division of the Webb Corp.

Worthington Distributors

Worthington Corp., manufacturers of construction, industrial, pumping, air conditioning and refrigeration equipment, announces the appointment of eight new distributors for Worthington Positioning Equipment, handling the corporation's full line of Welding Positioners and Power and Idler Turning Rolls.

Located in five different states, distributors are: Jackson Welding Supply Co., Rochester, N. Y.; Weldery Supply Co., Jamestown, N. Y.; Mills Welding Supply Co., 110 E. Utica St., Buffalo, N. Y.; Maine Oxy-Acetylene Supply Co., Auburn, Me.; Smith Courtney Co., Richmond, Va.; Gulf Welding Co., 1133 Magazine St., New Orleans, La.; and Delta Oxygen Co., Memphis, Tenn.

At the second Welding and Allied Industry Exposition, Joe MaGee, symbol of General Electric's welding products, literally comes to life in the form of a ventriloquist's dummy as he shakes hands with Dr. C. A. Adams, founder and first president of the American Welding Society. Looking on are R. C. Freeman, manager of the company's Welding Department, and Tommy Atkins, attractive girl ventriloquist

General Dynamics Introduces Consumable Insert Weld*

An effective answer to industrial welding problems brought on by the atomic era has been furnished American manufacturers by General Dynamics Corp.'s Electric Boat Division in Groton, Conn.

At the shipyard in this New England seaport where the submarine U.S.S. *Nautilus*, the world's first atomic-powered vessel, was launched on January 21st, technicians have developed a unique process for pipe joint welding which eliminates the use of backing rings and meets the exacting requirements of high pressures and temperatures called for by modern industry.

The new technique, termed the "Consumable Insert Weld," was demonstrated publicly for the first time at the AMERICAN WELDING SOCIETY show in Buffalo, N. Y., by the Arcos Corp., of Philadelphia.

It is reported that interest in the process throughout the United States has become so great that General Dynamics is now making a study of the establishment of patent rights.

Conventional welding to connect two pipes for either the use of a backing ring within the pipe, generally of the same material as the pipe, or the use of a conventional inert-gas-shielded tungsten-arc butt weld.

The use of the backing ring tends to produce crevices where the ring fits against the inside wall of the pipe. Radioactive particles have been found to collect in these crevices.

This danger is eliminated with the insert weld technique which is able to produce a sound butt-welded joint with a smooth surface free of cracks and crevices.

* Paper on this method of root pass welding was presented at the 1954 AWS National Spring Meeting and will be published in an early issue of THE WELDING JOURNAL.

AT THE FRONTIERS OF PROGRESS YOU'LL FIND

AN AIR REDUCTION PRODUCT

FOR WELDING AND CUTTING...

IN THE RED DRUM

HIGHEST QUALITY

DUST-FREE

NATIONAL CARBIDE

Write for the name and address of the NATIONAL CARBIDE supplier nearest you.

National Carbide Company

GENERAL OFFICES: 60 EAST 42ND STREET, NEW YORK 17, N. Y.

A DIVISION OF AIR REDUCTION COMPANY, INCORPORATED

The conventional inert-gas-shielded tungsten arc method employed up to the present showed deficiencies which resulted in "icicles," blowholes and crevices whenever extreme caution was not used in fit-up or preparation and in welder technique. The consumable insert weld requires neither close-tolerance fit-up nor extraordinary welder techniques.

A survey of fabricators and other potential users of the new technique shows a big demand for the process at any point where the installation is "critical" in temperature, pressure, corrosion, turbulence or a combination of these conditions.

Future applications of the insert weld process are unlimited, Electric Boat claims, especially in the stainless steel and alloy steel fields. This is particularly true, it is reported, in such industries as chemical, petroleum and gas, power generation, marine and shipbuilding, food and dairy, pulp and paper, and textile.

The insert weld method was developed by Theodore A. Risch, Welding Superintendent, and Herbert B. King, Welding Department Supervisor. Mr. Risch is a member of the Atomic Energy Commission's committee on welding.

The General Dynamics division has played a leading role in the application of atomic energy to propulsion. In addition to building the *Nautilus*, the shipyard is now constructing the *Sea Wolf*, second atomic-powered submarine, and is also engaged in two subcontracts for the AEC's installations at Oak Ridge, Tenn., and at the Hanford Works, Richland, Wash.

ECPD Survey on Awarding Professional Degrees

The Recognition Committee of the Engineers Council for Professional Development, under the chairmanship of R. H. Barclay, has completed a survey of the awarding of the professional degree by various engineering institutions. The survey, with its excellent response—of the 146 institutions sent questionnaires, 142 responded—will serve as a basis for formulating recommendations concerning the practice of awarding the professional degree as a means of professional recognition.

Of the engineering schools surveyed, 86 award the professional degree while 62 do not. Of the 86 awarding the degree, 74 use professional experience as a basis for awarding the degree, 8 require resident graduate study and 4 include both professional experience and resident graduate study as prerequisites for awarding the professional degree.

In regard to their future plans concerning the professional degree 69 colleges will continue awarding the degree, 2 will institute the professional degree, 13 will abandon it, 49 will continue not to award it and 17 are uncertain as far as future plans are concerned. The survey shows that approximately one-fifth of the schools offering the professional degree have either dropped it or are making plans to do so.

The Committee also reported an increase of approximately 80% in the awarding of professional degrees in the last five years as compared with the previous five-year period. In the last ten years, 1387 to 1398 professional degrees have been awarded, and of these, 917 to 922 have been awarded during the last five years.

The Committee believes this survey to be the most comprehensive of its type ever undertaken and will use it in formulating recommendations on the practice which they believe should be followed in respect to awarding the professional degree as a means of professional recognition.

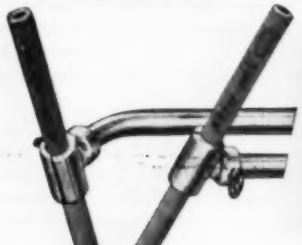
Tour Non-Destructive Testing Department Headed by Bell

The Non-Destructive Testing Department of Sam Tour & Co., Inc., is now headed by J. K. Bell. Sam Tour & Co., Inc., is an independent research, development and testing organization specializing in the chemical, mechanical, metallurgical, and nondestructive testing fields.

Mr. Bell is a graduate in Civil Engineering from New York University. Since

BECKER

KEEN-ARC CARBONS



FOR CONSISTENTLY GOOD RESULTS

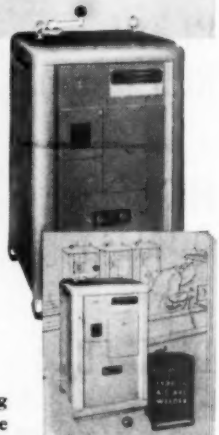
Designed to carry the high currents necessary for intense heat, BBB Keen-Arc Carbons produce a fine-grained weld of high tensile strength. They give a smooth, steady "flowing" flame which does not wander and which is concentrated at the desired focal point. Flame temperature is easily and accurately adjusted by merely changing the ampere input, and heavy copper coating permits gripping at extreme ends—eliminates frequent and periodic resetting.

A COMPLETE LINE OF CARBON WELDING SUPPLIES including carbon and graphite electrodes, carbon rods and plates, welding paste, etc. Write for catalog.

BECKER BROTHERS CARBON CO.

3450 South 52nd Ave. Cicero 50, Illinois

GET THIS NEW WESTINGHOUSE "TA" WELDER BOOKLET FREE



The Westinghouse "TA" Welder is completely new! And it's loaded with the most sensational line-up of welding developments yet introduced in one a-c arc welder.

CHECK THESE PLUS FEATURES

Thermal Overload Protection...Hot-Start . . . Single-Range Current Control . . . Weatherized Construction... more compact . . . light weight and wider operating range.

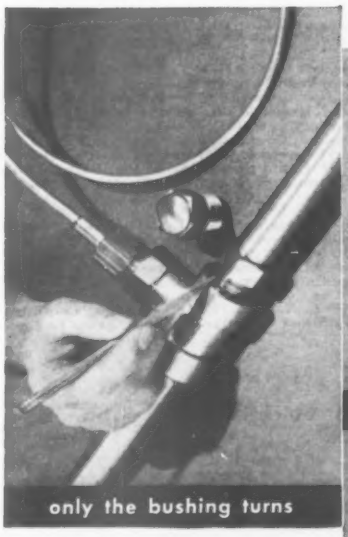
WANT PROOF?

See your nearest Westinghouse Welding Distributor for your copy of the 16-page book on the new "TA" and ask him for an actual demonstration, or write Westinghouse Electric Corporation, P.O. Box 868, Pittsburgh 30, Pa. J-21853

YOU CAN BE SURE...IF IT'S Westinghouse

compound Pressure

the new and better cylinder manifold...



The new compound pressure* cylinder manifold is made of the sturdiest die forgings and extruded rods; all are drilled for uniform inner dimension. The leak proof joint which results from the compound pressure design is tighter and more leakproof even than the well understood and long used connection between regulator and cylinder valve. The big improvement of this new invention lies in these facts: you can have any competent mechanic assemble a cylinder manifold to your own or our specifications with the assurance of absolute alignment and permanent leak proofness. Yet, the resulting cylinder manifold may be disassembled at any time, stored or moved and reassembled when required. It may be extended when needed, redesigned when desired, stored in bins as individual fittings. Only the bushings move in assembly, thus absolute alignment is certain.

*patents applied for

by

National SINCE 1910 of ...california

NATIONAL welding equipment company... 218 fremont street san francisco 5 california

535

completing his military service in the Signal Corps of the United States Army he has been a field engineer and boiler erector on power plants and high pressure boilers. Also, he has been a leading designer in connection with the design of chemical plants.

A member of the Society for Non-Destructive Testing and the AMERICAN WELDING SOCIETY, Mr. Bell is also the representative of Sam Tour & Co., Inc., on the American Society for Testing Materials Committee E-7 and its Subcommittees 2, 3, 5 and 6.

Diversey Sales Personnel

W. E. Noyes, Vice-President in charge of sales for the Diversey Corp., Chicago, recently announced the promotions of five men to new key sales positions within the Diversey sales department.

R. J. Stell was named manager of new product development, a newly created position; C. R. Reid was promoted to assistant general sales manager; E. M. Petrie has been appointed manager of Diversey's Technical Service department; M. J. Butler, Jr., was named advertising-sales promotion manager; and H. M. Pickels, Jr., has been appointed assistant to Vice-President Noyes.

The moves were said by Mr. Noyes to be part of the Company's aggressive plans for expansion in present and new markets. Diversey manufactures and sells cleaners, disinfectants and insecticides for food, industrial and institutional sanitation and prefinishing cleaners and etchers for the metal industries.

Eutectic Opens New Plant in Canada

Premises have been acquired by Eutectic Welding Alloys Company of Canada, Ltd., at 3150—37th St., Ville St. Michel, Montreal, P. Q., for the manufacture of its special-purpose alloys in Canada. A subsidiary of Eutectic Welding Alloys Corp., Flushing, N. Y., production will begin almost immediately and goods will be shipped direct from the plant.

Officers and Committee Heads at Fourth Conference on Electric Welding

Back row (left to right): (1) T. B. Wilson, Chairman, Meeting Facilities Committee, Acro Welder Co. (2) Alex Paalu, Chairman, Registration Committee, A. O. Smith Corp. (3) M. P. Cornelius, Member of Instrumentation for Resistance Welding Subcommittee, International Harvester. (4) Harold Lund, Registration Committee, A. O. Smith Corp. (5) J. G. Magrath, Secretary, American Welding Society. (6) J. B. Welch, Electric Welding Committee, Cutler-Hammer, Inc. (7) S. M. Kapell, Session Secretary, Westinghouse Electric. (8) L. P. Winsor, Electric Welding Committee, Rensselaer Polytechnic Institute. (9) A. U. Welch, Electric Welding Committee, General Electric Co. (10) J. H. Cahn, Session Secretary, Battelle Memorial Institute. (11)F. L. Brandt, Electric Welding Committee, Thompson Electric Welder. (12) H. D. Van Seiver, Session Chairman, Budd Co.

Seated (left to right): (1) G. I. F. Theriault, Session Chairman, General Electric Corp. (2) L. C. Poole, Session Secretary, Weltronic Co. (3) John A. Staley, Chairman, Hospitality Committee, John A. Staley Co. (4) Charlie Metz, Chairman, Plant Tour Committee, Aee Welding Supply. (5) E. J. Limpel, Conference Chairman, A. O. Smith Corp. (6) J. W. Brown, Chairman of Arrangements, Square D Corp. (7) H. W. Tietze, Chairman of Publication Committee, Public Service Electric & Gas Co. (8) Ray Young, Chairman of Publicity Committee, Public Service of Northern Illinois. (9) C. N. Clark, Electric Welding Committee, Duquesne Light Co. (10) Myron Zucker, Electric Welding Committee, Myron Zucker Engineering Co.

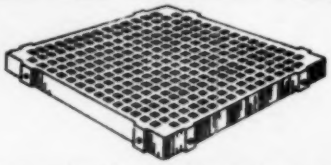
Fourth AIEE-AWS Conference on Electric Welding

The fourth conference on electric welding was completed at Milwaukee on May 21st when leaders and experts in the field met at five sessions during the 3-day meeting held at Hotel Schroeder. The conference was a joint enterprise of the American Institute of Electrical Engineers and the AMERICAN WELDING SOCIETY. The program was arranged by the AIEE Committee on Electric Welding under the Chairmanship of E. J. Limpel of A. O. Smith Corp., Milwaukee. Registration numbered 214 with the greater percent of those present representing leaders in field of arc and resistance welding.

The 19 papers presented covered fields of Inert Gas Arc, Fundamental Arc Research, Safety, Instrumentation, and Resistance Welding. Proceedings of the conference will be available shortly. They will include not only complete copies of papers but also transcripts of the discussions which were a special feature of this conference. Orders for these may be placed with R. S. Gardner at the National Headquarters of the American Institute of Electrical Engineers, 33 W. 39th St., New York 18, N. Y. The price is $3.50. A limited number of proceedings of previous conferences held at Detroit during 1948, 1950 and 1952 are also available.

The new bibliography on high-pressure arcs has just been received from the printer and was released during the session on Fundamental Arc Research. This publication is sponsored by the Subcommittee on Fundamental Arc Research under the AIEE Committee on Electric Welding. The Subcommittee has been working for several years on the project of compiling

WELDING and ASSEMBLY PLATENS



Floor plates — bending tables — layout tables — straightening tables — dog blocks — bending blocks — blacksmith blocks. 5'x5' — 6'x6' — 6'x8' — 6'x10' — 5'x10' — 6'x12' — 3'x3' — either 6" or 7" thick.

STAHL EQUIPMENT CO.
94 Washington St., Brookline Village 46, Mass.

UNITED STATES TESTING COMPANY, INC.

INSPECTION and TESTING of Welding and Weldments

QUALIFICATION of Procedures and Operators

Main Laboratories **Hoboken, N. J.**

Boston - Chicago - New York - Philadelphia - Providence

a list of all available publications on the subject. The published bibliography consists of 2450 entries of (*a*) the author's name, (*b*) the title of the article, (*c*) the name of the publication, (*d*) the volume number and date of publication and (*e*) the number of pages of the article and includes not only these written in English but also many foreign publications. Copies are available from AIEE headquarters for $1.50.

Four plant tours in the Milwaukee area were also a popular attraction this year. These inspection tours covered production of equipment and principal uses of arc-resistance-welding equipment and controls at A. O. Smith Corp., Cutler-Hammer, Inc., Square D Co. and Nash Motors Division of Nash Kelvinator Corp.

Standards Meeting

The Standards Engineers Society will hold a two day annual meeting at Atlantic City, N. J., Oct. 1 and 2, 1954. Registration will start at 9:30 A.M. Friday morning, Oct. 1. Headquarters will be at Haddon Hall.

The morning session will be devoted to a symposium on problems of special concern to companies' standards departments.

At a dinner meeting on Friday, Oct. 1, awards will be presented to individuals who have made outstanding contributions to the development of standards.

G. E. Welding School for Locomotive Employees

The General Electric Co.'s Locomotive and Car Equipment Department has initiated a volunteer welding training school which is open to anyone in the department wishing to learn special welding techniques or to those who just want practical welding experience.

It is expected that this new school will help the department's rapidly expanding Welded Product Unit solve the critical problem of obtaining additional supervisors and qualified welders.

Classes are held evenings and Saturdays and are attended by a cross section of the department's personnel including welders, inspectors, engineers, foremen and superintendents. Theory classes cover types of welds, joint preparation, fit-ups, splices and other subjects relative to high-quality welding. These theories are then applied in a special instruction area (see photo) where individuals can learn how to weld various types of material and practice until the technique is mastered.

Champion Rivet Sales Agents

The Champion Rivet Co., Cleveland, Ohio, manufacturers of Welding Electrodes, states that Walter E. Palmer, formerly Sales Manager of All State Welding Alloys, has been appointed sales representative in the New York area. Prior to his connecton with All State, Palmer was associated with Hollup Corp. for 27 years as manager of the Eastern Division. He has been a member of the AMERICAN WELDING SOCIETY for more than 20 years.

Walter E. Palmer

John R. Patnovic

John R. Patnovic will be the Champion Sales Representative in the Philadelphia area. Patnovic was formerly associated with Areway Equipment Co. in Baltimore and was an engineer with Radio Corporation of America. He also is a member of the AMERICAN WELDING SOCIETY.

G. E. welding school for locomotive employees

How easy can you get? If you can hold a wrench and a screw-driver you can put a new seat in a SMITH'S REGULATOR in just a few minutes time. No special tools—no special skills—no long delays. That's why experienced welders pick SMITH'S REGULATORS.

SMITH WELDING EQUIPMENT CORPORATION
Dept. WJ-91, 2633 S.E. 4th St., Minneapolis, Minn.

NEW PRODUCTS

Safety Tools

Through careful research and development with improved efficiency, balance and increased strength being the objective, Ampco Metal, Inc., of Milwaukee, Wis., now offers five new open-end wrenches.

According to Ampco, it is the only Safety Tool manufacturer offering this series of open-end wrenches as forgings. Forged to steel tool specifications, they have the same flexibility, balance and appearance with approximately 10% less weight due to the Ampco Alloys used in their production.

These features plus a 30% increase in strength, make this new line of Ampco open-end wrenches most attractive, especially since prices remain the same.

Hard-facing Rod

A new hard-facing rod developed specifically to withstand the combination of extreme abrasion and very heavy impact has been placed on the market by Mir-O-Col Alloy Co., of Los Angeles, 31, Calif.

Trade named "BR," the new rod is available for either electric or acetylene application. An outstanding characteristic claimed for the rod is its multiple pass feature. Worn parts originally rebuilt with "BR" can be rebuilt over and over again with the new metal forming a permanent bond with the previous deposit of "BR."

Field tested for many months prior to its introduction, the new "BR" rod is intended for rebuilding or hard surfacing such equipment as Crusher Jaws and Crusher Rolls, as well as other rugged service equipment.

A free sample of the new Mir-O-Col "BR" rod, along with informative literature, may be obtained without cost or obligation by writing to Mir-O-Col Alloy Co., 312 N. Avenue 21, Los Angeles 31, Calif.

Aluminum Solder

A new type solder, trade named AluTin 51, has been developed by Eutectic Welding Alloys Corp., Flushing, N. Y., for production, filling, sealing and repair operations upon wrought and cast aluminum alloys.

The core of this specially compounded alloy is a liquid flux which is claimed to have exceptional wetting properties. Surface tension is reduced and this permits the alloy to spread and flow out wherever the liquid flux has wet the surface. This accelerated tinning action facilitates bonding and permits high-strength, porosity-free deposits to be made.

The melting range is between 400 and 500° F and the alloy has a tensile strength up to 7000 psi. Any type of heat source may be used, oxy-acetylene, gas torch, furnace, induction or soldering iron. The low melting point of this alloy makes it particularly suitable for soldering iron applications.

Although primarily designed for aluminum, this solder is reported to give excellent results upon steel and other metals.

Further details may be had by writing to the Eutectic Welding Alloys Corp., 40-40 172nd St., Flushing 58, N. Y.

Stainless Steel Electrodes

A complete line of 15 different stainless steel welding electrodes designed for use with either ac or dc has been placed on the market by Pacific Welding Alloys Mfg. Co., Los Angeles 31, Calif.

According to the manufacturer, each electrode in the line has been carefully formulated and field proved to give an extremely fast rate of deposit, reduce spatter loss to an absolute minimum, create a very soft arc and to facilitate an exceptionally easy slag removal.

Pacific stainless steel welding electrodes are available in over 15 of the popular types. A free sample will be sent upon request to Pacific Welding Alloy Manufacturing Co., 310 N. Avenue 21, Los Angeles 31, Calif. Individuals requesting sample should specify electrode type and size, or indicate work to be done with the rod.

G-E "Fillerarc" Generator

General Electric's "Fillerarc" generator for consumable-electrode gas-shielded welding now is available as a separate power source, it was announced recently by the company's Welding Department.

Previously, the generator had been offered only as an integral part of the Fillerarc high-speed welding apparatus, which also includes a welding gun and wire drive unit.

Simultaneously, G-E announced a 15% reduction in the manufacturer's suggested resale price for Fillerarc equipment. This has been made possible by sales volume and improved production facilities in the Welding Department's new plant at York, Pa., a spokesman said.

The Fillerarc generator, rated at 450 amp continuously, is designed to maintain a constant arc length at all times. The unit has a rising volt-ampere characteristic and is completely self-regulating.

Once arc length is set, the operator can change wire feed (the only other variable to be controlled) even while welding, without readjusting the welder.

Capable of producing any current required up to its full rating, the generator will accommodate wire feeding speeds up to 750 ipm, and will supply the current necessary to melt off the wire at exactly the rate it is fed.

Arc Welding Benches with Shields

A new series of Arc Welding Benches with $36^1/_2$-x $36^1/_2$-in. tops that will stand without end or wall supports, has been introduced by Industrial Bench and Equipment Mfg. Co., Inc., of New Britain, Conn.

Fitted with a 30-in high glare shield on three sides, the new series of benches feature the exclusive Industrial Equipment design legs, electrically welded into formed sections. The bench surface is standard height ($33^3/_8$ in.). Arc welding benches come equipped with a bench drawer 18 x 22 x 5 in. and a shelf with partitions for holding welding rods. Not furnished as regular equipment, fire brick 9 x $4^1/_2$ x $2^1/_2$ in. can be easily and conveniently installed on the top. Choice

of lock or padlock attachment is available for the theftproof steel drawer, which will not bind or cramp no matter how full.

For additional information, write to Industrial Bench and Equipment Mfg. Co., Inc., 98 S. St., New Britain, Conn.

Lightweight Magnetic-Particle Test Unit

A new Norelco magnetic-particle test unit called Portaflux that weighs only 45 lb and is easily carried into a manhole or other confined spaces, has been announced by the Research & Control Instruments Division, North American Philips Co., Inc., 750 S. Fulton Ave., Mount Vernon, N. Y.

This unit is designed to locate surface defects in rough castings, bar stock, forgings and shop welds. It is useful for examinations at various stages of production; and during service for revision and repair. Easy portability makes the unit especially valuable on ship hulls, storage vessels, pipelines and other large objects where it is necessary to take test equipment to field locations.

Objects to be checked are magnetized either by passing a current directly through the metal or through a surrounding cable in the form of a coil. Magnetic iron oxide or precipitated iron powder is distributed over the surface of the magnetized object

and alignment of the particles is such that the defect is clearly located.

The new Portaflux unit has two heavy-duty, oil-resistant insulated cables with heavy-duty, renewable prods that carry currents up to 600 amp at a maximum voltage of 1.5 v. A special metal coupler is provided for connecting the prods together when it is desirable to use the wrap-around coal method.

The control panel has an indicating-type meter with a range of 0–600 amp. There is a three-way selection switch for different ranges and a pilot lamp indicates when the high range is in use.

A 6-v work lamp with magnetized base, extension cord and plug is provided for the convenience of the operator. In addition, a 110-v convenience outlet is built in to accommodate auxiliary equipment.

The Portaflux unit also has a novel indicating device which shows the direction of the flux in the magnetized object and indicates presence or absence of sufficient field strength.

The new magnetic-particle test unit takes power from any 110-v, single phase a-c convenience outlet through a cord and plug which is provided. The Portaflux measures 18 × 12 × 7 in. and weighs 45 lb.

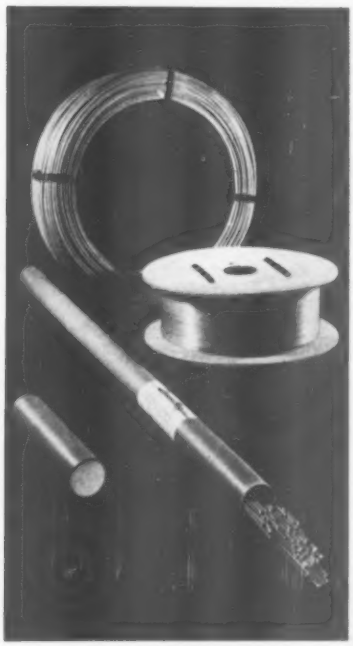
Additional information may be had by writing directly to manufacturer at above address.

Electron-Arc H.-F. Units

Electron-Arc, Inc., of 210 Broad St., Lynn, Mass., has introduced a vacuum tube type, high-frequency source for use in inert gas welding. It operates with any torch and welder combination, and provides improved cleaning action and closer control of the weld for smoother joint.

The Electron-arc Gas Saver is available in combination with the Electron-arc high-frequency unit or separately. It is claimed that this unit will effect savings on argon or helium gas consumptions by as much as 50%. The timer controls gas flow and protects hot electrode from oxidation, thus increasing tungsten life. Single dial permits variable time control.

Both units, standard, are powered by 110-v ac, 60 cycles. Other voltages and frequencies on special order. Literature available upon request.



FOR QUALITY WELDMENTS
use
Drawalloy
CORPORATION
QUALITY CONTROLLED
STAINLESS STEEL
WELDING WIRE

▶ available in Spools, Coils and Lengths

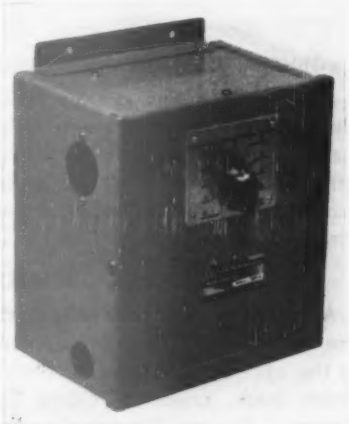
▶ for Automatic and Semi-Automatic gas and inert arc welding

Welding wire by Drawalloy is made to an exacting high standard . . . a high standard established by long-experienced welding men who know welding wire and how it must work. Set-ups for automatic and semi-automatic welding take more time than regular welding. That's why you want to be sure of satisfaction *before* you start. This *reliable* wire is weld-tested to give the best results every time. Write today for complete information and prices.

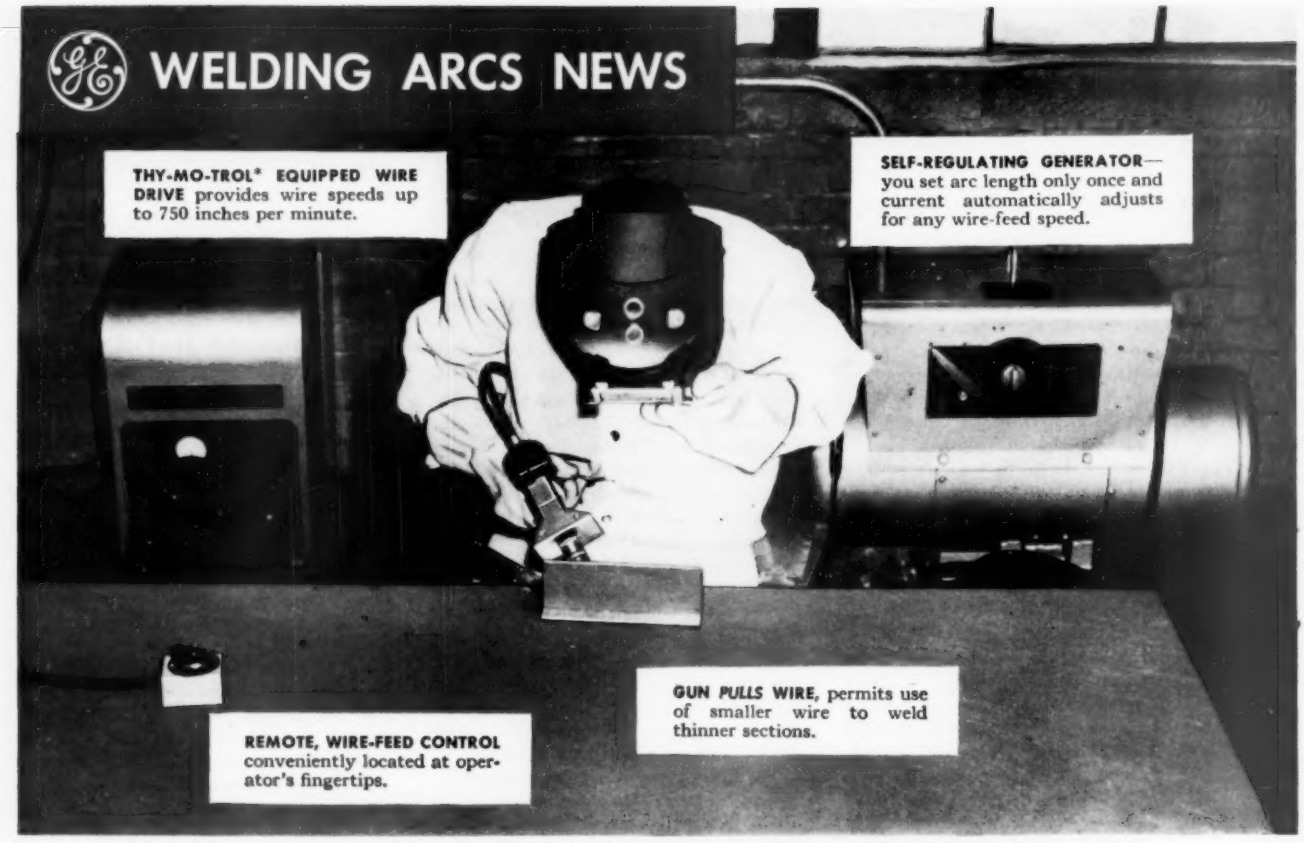
WELDING SUPPLY DISTRIBUTORS: Get prompt delivery on all sizes and grades of stainless and tool steel wire for gas and inert arc welding.

Drawalloy
CORPORATION
LINCOLN HIGHWAY AT ALLOY STREET • YORK 13, PENNSYLVANIA

Electron-arc H.F. 2



Electron-arc gas saver


WELDING ARCS NEWS
THY-MO-TROL* EQUIPPED WIRE DRIVE provides wire speeds up to 750 inches per minute.
SELF-REGULATING GENERATOR—you set arc length only once and current automatically adjusts for any wire-feed speed.
GUN PULLS WIRE, permits use of smaller wire to weld thinner sections.
REMOTE, WIRE-FEED CONTROL conveniently located at operator's fingertips.

FILLERARC IS THE ONLY COMPLETE EQUIPMENT DESIGNED ESPECIALLY FOR CONSUMABLE-ELECTRODE GAS-SHIELDED WELDING

Now—demand for these Fillerarc* features permits G.E. to reduce price 15 percent

Production economies resulting from heavy customer demand, and use of expanded manufacturing facilities at General Electric's new plant at York, Pennsylvania now make possible a 15% reduction in the price of Fillerarc equipment.

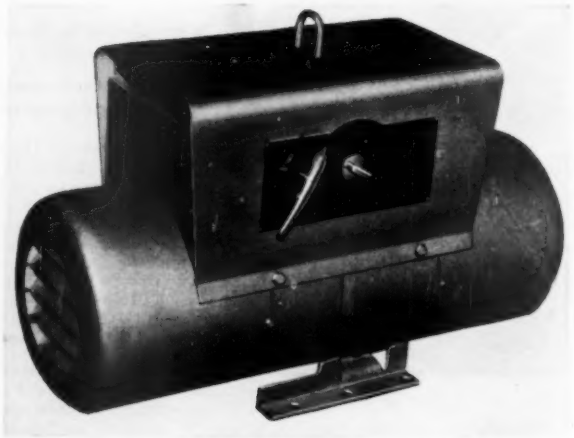
GENERATOR NOW AVAILABLE SEPARATELY

Also, you can now get the Fillerarc generator as a separate equipment. This self-regulating unit automatically supplies the right current to consume the amount of wire being fed. Once you set the arc length, current is correctly adjusted for every change in wire-feed speed.

CONTACT YOUR DISTRIBUTOR TODAY

Ask your nearest G-E welding distributor today for free bulletins on Fillerarc equipment. His name is listed on the opposite page and in the yellow pages of your phone book, under "Welding Equipment—General Electric." General Electric Co., Schenectady 5, N. Y.

*Registered trade-mark of General Electric Company.



G-E FILLERARC GENERATOR, now available as separate equipment, is the only generator with a rising volt-amp output characteristic. This minimizes burn-back, stubbing. For best performance with any consumable-electrode, gas-shielded equipment use this G-E power source.

TEST COMPARISON is made by Tractomotive Corp. employees between welds made with Strikeasy 1 and E-6012. Strikeasy 1 electrode welded 2 to 3½ times faster.

Tractomotive uses G-E Strikeasy 1 . . . increases welding speed 2 to 3½ times

General Electric powdered metal electrode is rapidly accepted by industry

Faster deposition rates . . . less operator fatigue . . . self-cleaning feature—these advantages of G.E.'s Strikeasy 1 contact electrode are being acclaimed by industry.

SAVE WITH STRIKEASY 1

The Tractomotive Corp. of Deerfield, Illinois has realized all these benefits of Strikeasy 1 in the welding of crawler tractor assemblies.

Says Tractomotive's general welding superintendent, S. E. Huffman, "Strikeasy 1 is that wonder electrode we've been needing for a long time. It's fast, practically self-cleaning and it produces a fine-quality weld. That means money saved, a boost in production, and a better all-round job."

USE FOR HIGH-SPEED JOBS

Strikeasy 1 conforms to AWS specifications for E-6012 electrodes in the flat and horizontal position.

Use Strikeasy 1 for those applications where the important factor is higher production speed. With this powdered-metal electrode, Tractomotive operators produced 21 inches of ⅜-inch fillet weld in 1½ minutes. The conventional E-6012 electrode filled the same length weld in 7½ minutes.

TEST STRIKEASY 1 ON YOUR JOB

Try Strikeasy 1 on any job where you are now using E-6012. See how it can speed up production and still produce the quality of weld you need.

For detailed information on this new standard in high-speed electrodes, see your nearest G-E welding distributor. His name and address are listed at the right.

710-18

G-E WELDING DISTRIBUTORS

Alabama: Birmingham—Alabama Oxygen, Young & Vann Supply; Mobile—Turner Supply

Arizona: Phoenix—Consolidated Welding Supply

California: Fresno, Los Angeles, Oakland, Sacramento, San Diego, San Francisco, Ventura—Victor Equipment

Colorado: Boulder, Colorado Springs, Denver, Durango, Ft. Collins, Ft. Morgan, Greeley, LaJunta, Longmont, Pueblo, Sterling—Hendrie & Bolthoff

Connecticut: Hartford, New Haven—Harris Company

Florida: Hollywood—Florida Gas & Chemical

Georgia: Atlanta, Macon—Welding Supply & Service; Augusta—Marks Oxygen; Columbus—Williams Welding Supplies

Idaho: Boise—Olson Manufacturing

Illinois: Chicago, Moline, Morton, Rockford—Machinery & Welder

Indiana: Evansville—Drillmaster Supply; Ft. Wayne, Indianapolis—Sutton-Garten; South Bend—Perry Welding Sales & Service

Iowa: Des Moines—Machinery & Welder

Kansas: Wichita—Standard Products

Kentucky: Louisville—Reliable Welding; Paducah—Henry A. Petter Supply

Louisiana: Alexandria, Shreveport—Hughes Oxygen; New Orleans—Consolidated Welding Supplies

Maryland: Baltimore—Arcway Equipment

Massachusetts: Boston—New England G-E Welding Sales Division

Michigan: Detroit—Welding Sales & Engineering; Grand Rapids—Miller Welding Supply

Minnesota: Duluth—W.P.&R.S. Mars; St. Paul—Production Materials

Mississippi: Jackson—Jackson Welding & Supply

Missouri: Kansas City—Hohenschild Welders Supply; St. Louis—Machinery & Welder

Montana: Billings—Valley Welders Supply; Billings, Bozeman, Cut Bank, Glasgow, Great Falls, Havre, Kalispell, Miles City, Shelby, Sidney, Whitefish—Valley Motor Supply; Butte, Great Falls—Montana Hardware

Nebraska: Lincoln—Lincoln Welding & Supply; Omaha—Baum Iron

New Jersey: Kenilworth—Welding Sales Corp.

New Mexico: Albuquerque—Industrial Supply Co.; Hobbs—Western Oxygen; Las Cruces, Silver City—Car Parts Depot, Inc.

New York: Buffalo—Welding Equipment Sales; New York—Welding Sales Corp.; Syracuse—Welding Engineering & Equip.

North Caroline: Charlotte—Dixie Gases; Gastonia—Gastonia Motor Parts

North Dakota: Bismarck, Fargo—Acme Welding Supply

Ohio: Akron, Cincinnati; Cleveland, Columbus, Dayton, Mansfield—Burdett Oxygen; Toledo—Odland Iron Works

Oklahoma: Oklahoma City—Hooper Supply

Oregon: Eugene, Portland—J. E. Haseltine; Medford, Portland—Industrial Air Products

Pennsylvania: Allentown, Philadelphia, Pittsburgh—Arcway Equipment

South Carolina: Columbia, Greenville—Welding Gas Products

South Dakota: Deadwood—Hendrie & Bolthoff

Tennessee: Chattanooga, Knoxville, Nashville—Welding Gas Products; Memphis—Delta Oxygen

Texas: Abilene—M&M Welding Supply; Alice, Corpus Christi—Crane Welding Supply; Alpine, El Paso, Marfa, Pecos—Car Parts Depot; Amarillo—Welding Equipment & Supply; Beaumont—H. & W. Welding Supply; Brownsville, Harlingen—Acetylene Oxygen; Dallas—Hill Equipment & Supply; Houston—G-E Welding Sales Division; Lubbock—Welders Supply of Lubbock; Midland—West Texas Welders Supply; Odessa, Pecos—Western Oxygen; Orange—Marine & Petroleum Supply; Pecos—Welding Supply Co.; Plainview—Plains Welding Supply; San Angelo—Southwestern Welding Supply; Texarkana—Hughes Oxygen; Wichita Falls—Nortex Welding Supply

Utah: Salt Lake City—The Galigher Co.

Washington: Seattle, Spokane—J. E. Haseltine; Spokane, Yakima—Industrial Air Products

West Virginia: Bluefield—Bluefield Supply; Charleston—Virginian Electric; Huntington, Logan—Logan Hardware & Supply

Wisconsin: Milwaukee—Machinery & Welder

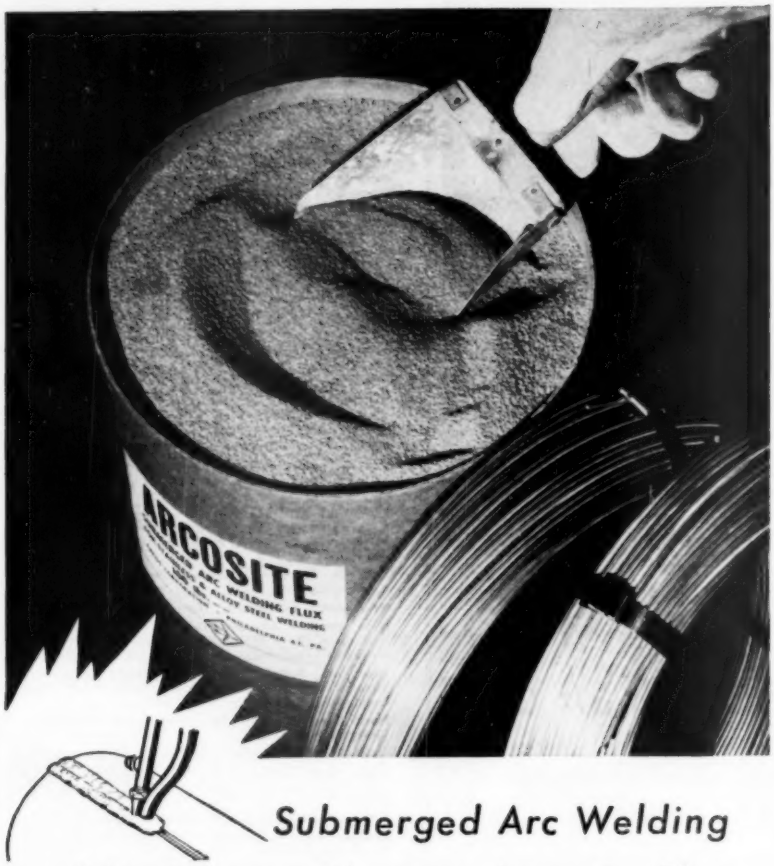
Alaska: Anchorage—Northern Supply

Canada: Toronto—Canadian G.E.

Hawaii: Honolulu—American Factors, Ltd.

GENERAL ELECTRIC

ARCOS FOR FINEST QUALITY WELDS



Submerged Arc Welding of Stainless with **new** Arcosite Flux

Now, for the first time, you can apply the economy of submerged arc welding to stainless steels. No longer need you worry about cracking, or poor transfer of the essential stainless elements. The combination of *new* ARCOSITE FLUX and *new* ARCOS CHROMAR (Stainless Steel) WIRE provides a balanced analysis for sound, dependable welds on every job. It's another example of how Arcos experience with coated electrodes and weld metallurgy is being translated into tangible benefits for you.

Write today for the Arcosite Flux Bulletin and see how you may profit from these two *new* Arcos products. Arcos Corporation, 1500 South 50th Street, Philadelphia 43, Pennsylvania.

WELD WITH ARCOS

STAINLESS WIRE AND ARCOSITE FLUX

Medium Duty Welding Torch

A new medium duty welding torch that is claimed to be more rugged, yet lighter, than any heretofore available in the medium duty field has been announced by National Cylinder Gas Co. The new Torchweld "45," according to NCG, welds steel from 28 gage to $\frac{1}{2}$ in. thick, making it particularly suitable for pipe welding, automotive welding and sheet metal fabrication.

The rugged but light construction is made possible by a new concept in design—a solid aluminum handle, with integral valve body and brass tubes. At just 11 oz., including mixer, it is said to be lighter in weight than any other torch of comparable capacity.

NCG reports that extensive field tests have proved the Torchweld "45" not only resists abuse but is easy to handle and reduces operator fatigue.

Valve wheels positioned at the front of the handle allow instant adjustments with the torch hand. The mixer employs the NCG Stab-L-Flow antiflashback principle and has Gas-Tite seating rings which permit tips to be attached with hand tightening.

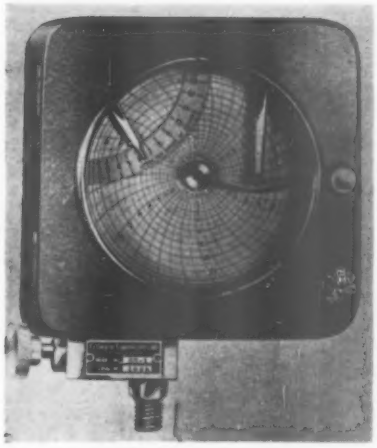
Two complete series of swaged welding tips, one-piece and screw-in style, are available in 12 sizes. The one-piece tip produces a flame with a semipointed cone which permits maximum heat concentrations on small areas. The screw-in type gives a semiblunt flame cone and is exceptionally resistant to abuse.

A special cutting attachment converts the torch into a cutting torch with capacity for cutting steels $\frac{1}{8}$ to $1\frac{1}{2}$ in. thick. A leakproof coupling can be made with hand tightening.

Argon Gas Flowmeter

A new indicating and recording flowmeter, designed to give an accurate record of argon gas or oxygen flow, has recently been announced. According to the manufacturer, it answers a longstanding need for a charted record for use in controlling and determining argon gas welding costs. It is adaptable to either a regulated cylinder supply or a piped system.

The meter permanently records argon gas or oxygen flow for 24-hr or lesser periods on an easy-to-read chart. This permits convenient charting of individual job billing costs. A quick check of welding



apparatus is provided at all times. Insufficient flow can be immediately detected.

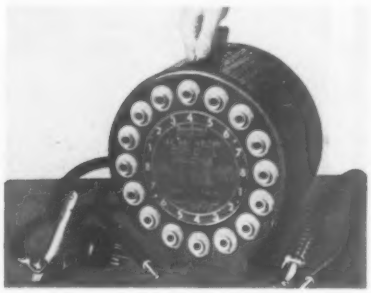
Two models are available: with 4½-in. chart for ranges from 0–15 lpm to 0–100 cfh and with 10-in. chart for ranges from 0–25 to 0–300 cfh. Both are furnished for inlet pressures at either 20 to 50 psi, as specified.

Flow rate is controlled by a built-in needle valve or can be controlled by equipment connected to the meter. Operation is mechanical, utilizing input pressure to actuate the indicating and recording mechanism. No lubrication or other maintenance is required. A self-contained ink supply is always available for filling the pen.

Further information is available from Elematic Equipment Corp., Department WJN, 6731 S. Chicago Ave., Chicago 37, Ill.

New 200-Amp Portable Transformer

A portable arc welder weighing but 65 lb and operating on either 110 or 220 ac 60 cycles with a rated output of 200 amp, is manufactured by Brennen Bucci and Weber, Inc., and is available from Kasson Die & Motor Corp., 32-14 Northern Blvd., Long Island City, N. Y. Called the "Bren/Weld" Portable Arc Welder and actually delivering 250 amp, it incorporates a new ultra high efficiency transformer, whose recent development makes it possible.



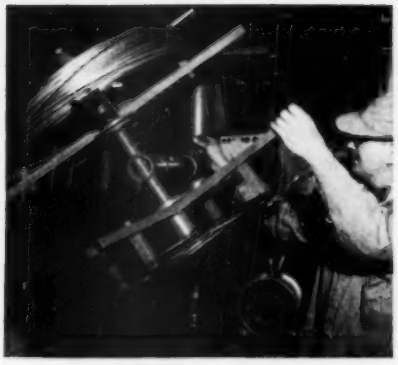
ARCOS FOR FINEST QUALITY WELDS

Mountains crumble as welded jaws bite in

Modern power shovels gulp truckloads of rock and dirt at one bite. It's a good example of how *welded* high tensile steels make possible bigger payloads—provide extra strength and toughness to reduce maintenance.

An important factor in this achievement is the quality of weld metal. That's why so many fabricators today specify Arcos Low Hydrogen Electrodes when welding low alloy high tensile steels. *On any job* demanding shock and abrasion resistance . . . maximum strength and ductility, the excellent properties of Arcos weld metal assures the results you want in service. Arcos offers quality weld metal and technical assistance that is second to none. Arcos Corporation, 1500 South 50th Street, Philadelphia 43, Pa.

WELD WITH ARCOS LOW HYDROGEN ELECTRODES



Change-over from one reel to the other takes only seconds. No lost time in reel changing.

Reversible finger-tip control permits variable speed control of the work-handling motor.

Angle positioner is worm-gear driven by the same motor driving the V'd rollers.

Now . . . for submerged arc welding and hardfacing

THE NEW AMSCO LEADER AUTOMATIC ELECTRIC WELDER

Pioneered by Leader . . .

Purchased by Amsco . . .

Proved by years of field use

Here, at last, is a complete electric welding unit in one package, designed to combine all the essential needs of job shop operation, production manufacturing and automatic hardfacing in a single, efficient machine.

Developed and field tested, the world over, for more than four years, it is now available through Amsco Distributors. (Amsco purchased the Leader Manufacturing Company late in 1953.) It joins a proved line of automatic and manual welding rod, electrode and manganese steel shapes long recognized for their part in the fight on the problem of wear.

In fact, the addition of the Amsco Leader line now gives Amsco Distributors the most complete line of hardfacing and wear-resistant materials on the market today. A fact that will mean cost savings to you the sooner you get acquainted with the Amsco Distributor in your town.

Call him today. Make a date to see the great, new Amsco Leader automatic electric welder. Ask him for your copy of the Amsco Leader folder, giving complete description and specifications of this versatile machine.

AMERICAN MANGANESE STEEL DIVISION

Chicago Heights, Illinois

Brake Shoe

to be absolutely sure
make certain you use . . .

ARCALOY

STAINLESS STEEL ELECTRODES

- *Controlled* high quality
- *Properly* formulated coatings
- *Uniform* welding characteristics
- *Analyses* for all A.I.S.I. stainless steel grades
- *Packaged* in hermetically sealed metal containers

Alloy Rods Company's *one job* is to make the finest electrodes. This specialization permits the highest standards of quality control throughout the entire production cycle—from the proper analysis of the core wire and the application of the correct coating to the finished electrode.

ARCALOY'S superior coatings produce a slag that is easily and completely removed and that saves expensive labor time. But most important of all, ARCALOY electrodes are *reliable*. The closely controlled quality supervision under which they are produced will give you top-flight, uniformly excellent welding, month after month.

ARCALOY Stainless Steel Electrodes are available for all grades of chrome-nickel and straight chrome stainless steels with either AC-DC coating or lime coating. Your Alloy Rods distributor will supply the right electrodes for your corrosion and heat resisting services . . . send your order today.

OVEN FRESH! ARCALOY Electrodes are packaged in the familiar ALLOY RODS red-and-yellow hermetically sealed metal containers. Available in 1/16", 5/64", 3/32", 5/32", 3/16" and 1/4" diameters.

Alloy Rods Co.

General Offices and Plant • York 3, Pennsylvania
Pacific Coast Sales Offices and Plant • El Segundo, Calif.

ARCALOY Stainless Steel Electrodes • BRONZE-ARC Phosphor Bronze Electrodes • NICKEL-ARC Electrodes for Cast Iron • TOOL-ARC Electrodes for Tools and Dies • WEAR-ARC Hard-Facing Electrodes WELD-ARC Low Hydrogen Electrodes

no finer electrodes made . . . anywhere

The "Bren/Weld" Arc Welder can be used to braze, cut and preheat as well as weld steel, up to and including $1^1/_2$ in. thick.

The "Bren/Weld" Portable Arc Welder handles electrodes from $^5/_{64}$ in. up to and including $^5/_{32}$ in., using either metallic or carbon arc process. Housed in a cast-aluminum case, dimensions are approximately 11 × 12 × $7^1/_2$ in. It is supplied complete with 7 ft of welding cables, electrode holder and ground clamps.

Caddy Taper-Lok Quick Connector

Erico Products, Inc., has announced the introduction of Caddy Taper-LOK Quick Connector, a positive locking connector featuring the Cadweld Connection, plus durable rubber insulators anchored to the welding cable.

It has the following features, according to the manufacturer:

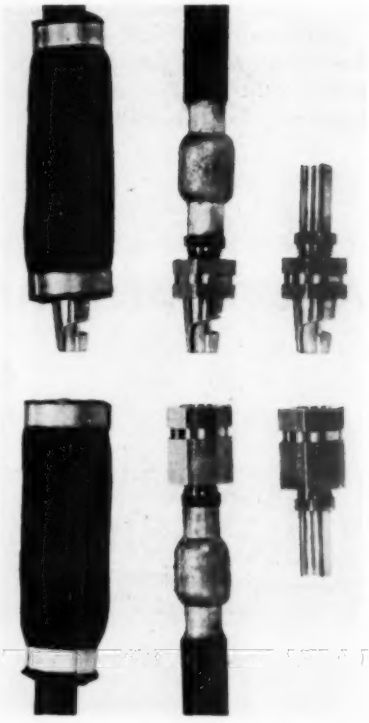
(*a*) Cadwelded connections: Permanent connections; high conductivity; cool operation.

(*b*) Positive wedging action: Greater current capacity due to high pressure contact between connector surfaces.

(*c*) Positive locking action: Cannot pull apart in service; easily disconnected.

(*d*) Durable rubber insulation: Not damaged by impact; no possibility of arcing; any size welding cable can be used.

(*e*) Insulation punch-lok banding method: Prevents cable insulation "creeping" and pulling out of connector insulation.



(*f*) Female end (hot line) protection: Prevents arcing when male is disconnected.

(*g*) 500 amp capacity: Suitable for all type operating conditions.

(*h*) Able to withstand vertical or horizontal pull: Punch-Lok hose banded grip on cable insulation and quick connector halves.

(*i*) Replaceable stud: Saves money when replacing old or broken cable.

For additional information, please write to Erico Products, Inc., 2070 E. 61st Place, Cleveland 3, Ohio.

Tempilstiks Crayons

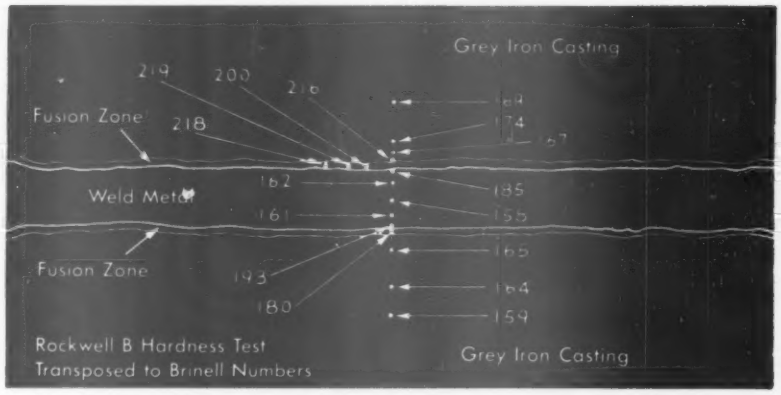
The Tempil° Corp. has just announced that Tempilstiks° for 413 and 438° F are now regularly available. These newly added temperature indicating crayons make it possible to determine temperature intervals intermediate to 400, 425 and 450° F for which Tempilstiks° have been previously manufactured. Tempilstiks° for 463 and 488° F are under development.

Tempilstiks° are now available in the range 113 to 450° F in 12½-deg intervals, in the range 450 to 550° F in 25-deg steps, and in 50-deg intervals from 550 to 2000° F.

Induction Heating Production Tool

A new design in high-frequency induction heating equipment has been announced by Electric Arc, Inc., of 152 Jelliff Ave., Newark, N. J., long-time manufacturers of Low Frequency Heaters and AC-DC Welders. Called the Kilotron, Models K400 10C and K400 20C, the units combine both current generator and work table in a single cabinet. Rated outputs are a full 10 or 20 kw and the units are rated for continuous duty. The salient feature of the console cabinet design is the large and unobstructed 33 x 100-in. work table which forms the top of the generator cabinet. It is claimed that this, and other features facilitating setup and operation make the new unit a highly efficient production tool with remarkable flexibility. The Kilotron is readily adapted to all types of induction heating operations.

Wide application possibilities are expected for the Kilotron by the manufacturer. Induction heating is a technique which can be applied with any conductive material, metallic or otherwise. Extremely high temperatures can be induced within a few seconds, if need be, by this method. Most frequent uses are for heat treating, stress relieving, hardening,



This drawing shows an actual test made on a machined casting welded with Nickel-Arc. Notice that the fusion zone of the weld is less disturbed or affected by the heat of welding and remains well within the machinable range. Notice also that the weld metal has a hardness that matches that of the base metal.

Better Machinability of Cast Iron with NICKEL-ARC

...and here's proof!

Nickel-Arc's special coating keeps welding heat down! The special coating used in Nickel-Arc makes it possible to weld in a lower amperage range, reduces the heat and resulting hard carbides in the weld area. Moreover, Nickel-Arc's AC or Straight Polarity DC operation provides a low-penetrating, easy-to-control arc free of spatter. With Nickel-Arc, therefore, there is always less disturbance in the base metal, and *better machinability* in the line of fusion.

Nickel-Arc's controlled balance between core wire and coating prevents cracking and porosity! Step-by-step control during manufacture maintains this balance. That's why Nickel-Arc produces a dense, sound, ductile weld deposit free from transverse cracks, porosity, and hairline cracks.

Find out how Nickel-Arc can help solve your cast iron welding problems. Order a 10-pound can from your Alloy Rods distributor . . . he has it in 3/16", 5/32", 1/8", and 3/32" diameters.

OVEN FRESH! Packaged in the familiar Alloy Rods red-and-yellow hermetically sealed metal container, every Nickel-Arc electrode reaches you in "oven-fresh" condition.

Alloy Rods Co.

General Offices and Plant • York 2, Pennsylvania
Pacific Coast Sales Offices and Plant • El Segundo, Calif.

ARCALOY Stainless Steel Electrodes • BRONZE-ARC Phosphor Bronze Electrodes • NICKEL-ARC Electrodes for Cast Iron • TOOL-ARC Electrodes for Tools and Dies • WEAR-ARC Hard-Facing Electrodes WELD-ARC Low Hydrogen Electrodes

no finer electrodes made . . . anywhere

brazing and kindred production operations; but, there are other applications where this technique permits large scale production not otherwise attainable. With no physical connection between the equipment and the work item required, the technique lends itself easily to problems like the heating of electronic tube elements while vacuum pumping. The exact temperature needed to adequately degassify, without impairing the element, can be attained automatically using the Kilotron.

The table top is of stainless steel, backed by insulation to eliminate reverberation and heat transfer. Formed edges of the table prevent work from falling off, and permit the table top to be used as a tray for quenching solutions. The operator stands or sits with the control panels at either side within easy reach. Control is manual or automatic at will. Provision has been made for remote control. Panel lights give continuous indication of all operating conditions. Full protection is provided for the operator and the equipment against accidental application of power, and the unit conforms to all requirements of the National Electrical Manufacturers Association and the FCC.

Additional information may be obtained by writing directly to the manufacturer at the above mentioned address.

Aronson Welding Positioner

Aronson Machine Co., Arcade, N. Y., manufacturers of welding positioners, announces the introduction into their line of precision Headstocks-Tailstocks their new Infinitely Variable Speed Headstock, Model HS16V, 16,000 lb capacity. Table rotation speed range is from 0 to 0.57 rpm, controlled by a micrometer dial type indicator with 37 major graduations and 10 micrometer marks per major graduation, making a total of 370 marked settings, each of which changes speed only 0.0016 rpm. The drive is equipped with magnetic braking which automatically brings the table to a smooth, quick stop. All working parts are enclosed within the

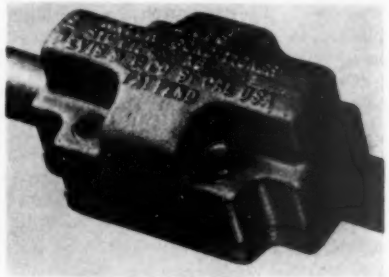
chassis as seen in the photograph, offering complete protection from damage by heavy objects, dust and foreign matter. The electrical control is by magnetic reversing starter with the dust-tight, oil tight remote push-button station operating on low voltage for safety. There are no belts or other parts to wear out or require adjustment. This new Variable Speed Headstock is equipped with Mercury Grounded main spindle for perfect conduction of welding ground current of any magnitude. The large faceplate table is supported by roller bearing backing rollers. All bearings are antifriction and all gears precision cut, welded steel. The most common application for the HS16V is found in automatic welding of large cylindrical work, quite often with the outer end supported on the Aronsen Model IR12, precision Idler Roll.

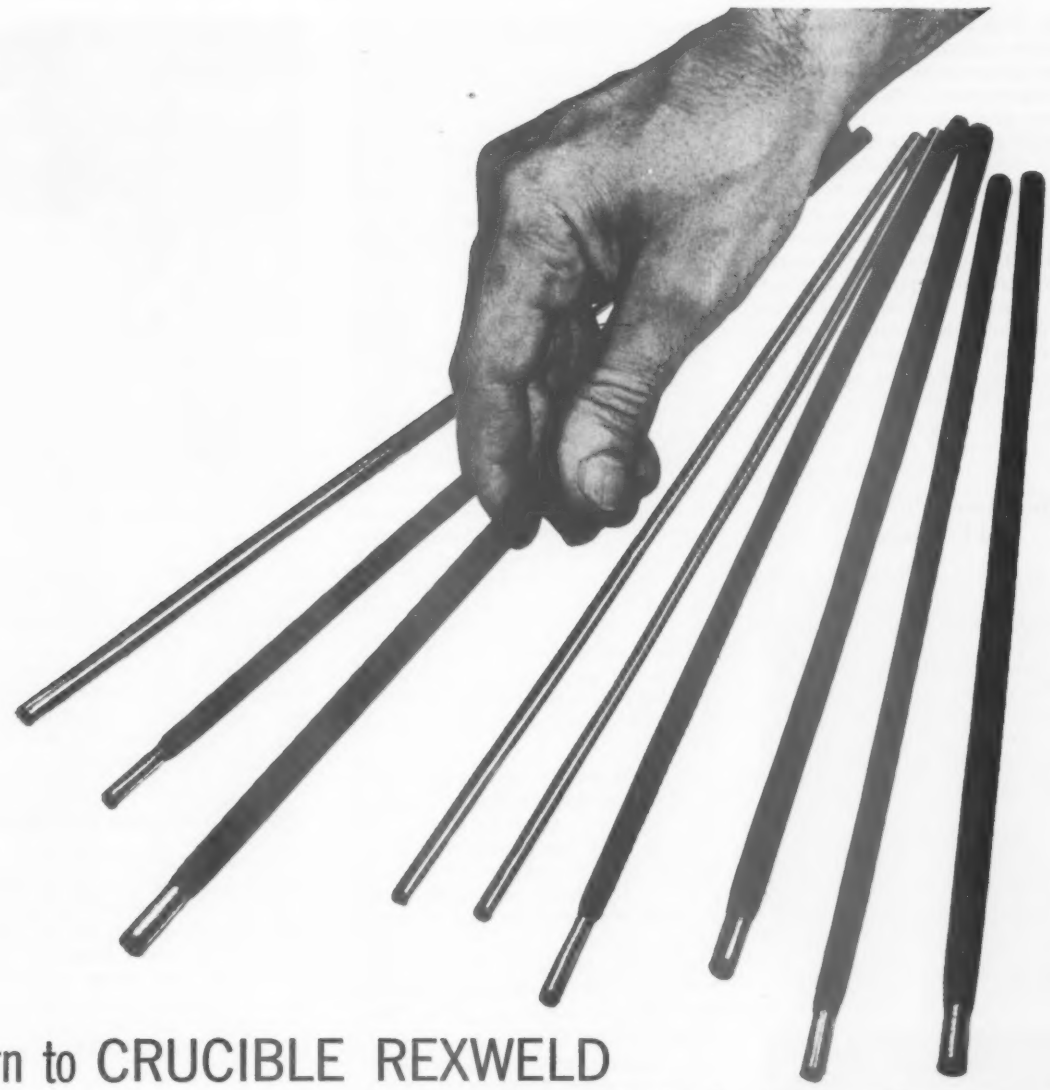
Additional information is available upon request to Aronson Machine Co., Arcade, N. Y.

Worth Looking Into!
MANGANAL
U.S. Patents 1,876,738—1,947,167—2,021,945
11%-13½% MANGANESE-NICKEL STEEL
WEDGE BARS
REPOINT WORN SHOVEL and DIPPER TEETH
faster, more economically . . . and far outlast new teeth.
• 23 SIZES AVAILABLE FOR ALL CONDITIONS OF WEAR.
SEND FOR LITERATURE
Mill Depot Stocks: Newark • Wilkes Barre (Forty-Fort) Indianapolis • Chicago
NEAREST DISTRIBUTOR UPON REQUEST
SOLE PRODUCERS 92 N. J. RAILROAD AVE. NEWARK, N. J.

Water Conditioning Unit

An improved type water conditioning unit has been announced by the Evis Manufacturing Co. of San Francisco. According to J. T. Voorheis, the concern's president, two years of development effort resulted in this greatly simplified product design. The Evis water conditioner has, during the past five years, gained wide industrial, commercial and domestic acceptance for correcting costly water





turn to CRUCIBLE REXWELD low hydrogen coated electrodes for superior welding characteristics

Crucible Rexweld low hydrogen coated electrodes provide greater ease of application. Welding can be done efficiently in both vertical and horizontal positions. And you get denser welds — less porosity, when you use Rexweld.

So, to simplify the hard-facing of hardenable steels, extend the life of parts, and cut operating costs, use Rexweld. Your nearest Crucible warehouse has Rexweld low hydrogen coated electrodes, and bare rods, in a wide assortment of sizes and grades to meet all your needs.

CRUCIBLE first name in special purpose steels

54 years of Fine steelmaking

REXWELD HARD SURFACING RODS

CRUCIBLE STEEL COMPANY OF AMERICA, GENERAL SALES OFFICES, OLIVER BUILDING, PITTSBURGH, PA.

REX HIGH SPEED • TOOL • REZISTAL STAINLESS • ALLOY • MAX-EL • SPECIAL PURPOSE STEELS

problems. It is said to effectively arrest mineral scale formation in piping systems and water-using equipment and to solve other problems economically.

The new design, being of the external or clamp-on type, avoids water service shutdown during its installation. Mr. Voorheis adds that the installation time requirement has been reduced to a minimum. Because the new unit comes in contact with pipe exteriors only it escapes hydraulic limitations ordinarily imposed by water pressure. For the same reason it is not exposed to deterioration by chemically active waters. Present plans of the company are to continue manufacture of its earlier in-line models along with the new type.

New Arcos Products and Processes

A new method of packaging electrodes, a new flux for submerged arc welding of stainless, a new line of specialty stainless steel wire, a new weld insert for welding stainless pipe, and a newly developed line of products for welding aluminum have been announced by the Arcos Corp.

Several important advantages are claimed by Arcos for their new method for protecting electrodes in shipment and storage.

The new container, known as the Arcos "Electropak," is opened simply by stripping the tape and lifting the metal lid. No cutting or breaking open is required. It is closed merely by pushing the lid on again. A recessed rim provides a tight closure against moisture and spilling.

Electropak Container

A sheet of aluminum foil between the outer and inside walls prevents moisture pickup. This sheet, plus alternating layers of ammunition board and asphalt is said to provide an excellent vapor barrier seal. Besides being naturally strong, the ammunition board is also resilient. This cushions the electrodes inside the package and prevents chipping of the coatings.

By combining a new type of flux, known as Arcosite Flux, with a new stainless steel wire, called Arcos "Chromar," the manufacturer reports that it is possible to eliminate the danger of cracking or poor transfer of the essential stainless elements during the welding of stainless and alloy steels by the submerged arc welding process.

Arcosite flux is suitable for welding the chromium-nickel (austenitic) stainless steels, the straight chromium (ferritic) stainless steels and the chromium-molybdenum (martensitic) stainless steels. Chromar welding wires are recommended for best results with this flux.

A complete new line of "Chromar" stainless steel wire has been developed by Arcos for welding chrome-nickel, straight chrome or chrome-molybdenum steels. The new wire is claimed to give sound, welds with the submerged arc, inert gas oxy-acetylene or atomic hydrogen methods. It is available in 17 different compositions in level-layer wound spools, coils and straightened and cut bundles. Standard coils have an inside diameter of 12 in. and a width of approximately $2^1/_2$ in.

Arcos also presents the new "EB" Weld Insert developed by the Electric Boat Division of General Dynamics Corp. This refers to a welding process as well as a specially shaped material used in that process. The insert used in this process is completely fused by a conventional inert-gas-shielded tungsten-arc torch. The process permits the deposition of a root pass which is smooth and uniform on both sides even though the actual welding is done on one side only.

A complete selection of "Alumnar" products has been developed by Arcos for use in aluminum welding. These are produced in the forms of level-layer wound spools, coiled, straightened and cut and coated electrodes.

Electric Hoist

American Engineering Co., Philadelphia, Pa., announces an addition to its line of hoists . . . a radically new Lo-Hed Electric Hoist with welded steel chassis, made in the popular 2- and 3-ton capacities. While retaining the balanced design basic in all Lo-Heds—drum on one side, motor on the other—it incorporates all the latest developments in both engineering and materials.

In addition to its lightweight welded steel chassis, the new Class BB Lo-Hed Hoist features heat-treated alloy steel, straight line, 3-reduction spur gears; automatic Weston heavy-duty type lowering brake; heavy-duty hoist and crane type motor; single-speed pushbutton control, 110 v at the pushbutton, without premium

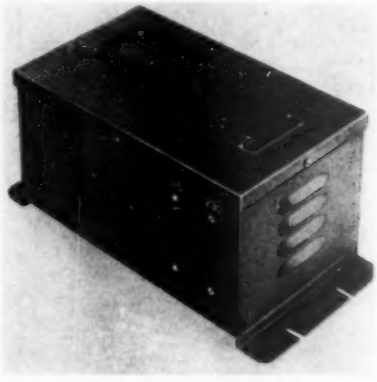
Electric Hoist

price; completely shrouded, all-steel safety type bottom block, ball-bearing sheaves, hook carried on antifriction thrust bearing.

A fully descriptive folder on this new Class BB Lo-Hed Electric Hoist will be sent upon request. Write to American Engineering Co., Aramingo Ave. & Cumberland St., Philadelphia 25, Pa.

Portable Booster Transformers

Marcus Transformer Co., Inc. of Rahway, N. J., have announced the marketing of their new Portable Booster Transformer. This new and compact unit is designed to restore the proper voltage level on lines where inadequate voltage is encountered due to overloaded systems. Easily plugged in to any line, the Marcus Booster Transformer has a capacity of 3000 or 3 kva, and



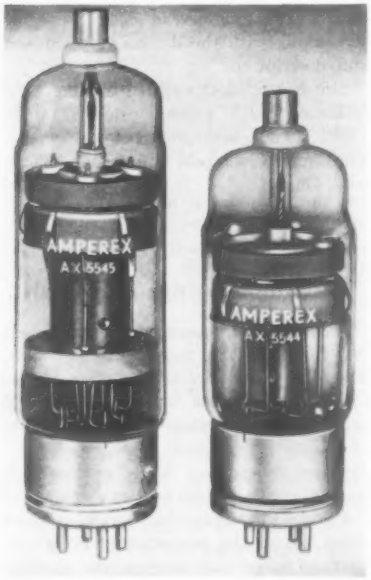
has an exceptionally high dielectric and thermal stability. It is wound with silicone enamel wire and has twist-lock plugs and outlets for safe connections. The Marcus Booster Transformer is ideal for any applications where appliances or machines are not operating at top efficiency due to low line voltage. It is equipped with plugs and outlets for 95, 105, 115 and 208

v to deliver 115 and/or 230 v in any combination.

Additional information may be had by writing directly to the company at the above address.

Thyratron Tubes

Two standard thyratron tubes, specifically designed for electronic control purposes such as the speed of d-c motors, counting and sorting devices, etc., have been announced by Amperex Electronic Corp.



Designated as Amperex types AX-5544 and AX-5545, these tubes are directly interchangeable in every respect with RETMA tubes bearing the same designation.

Both of these tubes are three-electrode, Xenon-filled thyratrons, with negative control characteristics. The inert gas filling allows reliable operation at maximum ratings over a wide temperature range.

Typical applications for these Amperex tubes include: the electronic control of the spee d-c motors, regulation of current and voltage, counting and assorting devices, and electronic switching. Complete data are available from the Engineering Department, Amperex Electronic Corp., 230 Duffy Ave., Hicksville, L. I., N. Y.

Inert-Gas Spot Welding with Aircospot

The Aircospot Gun, a recent Airco development, was demonstrated in Buffalo, N. Y., at the American Welding Society sponsored Welding and Allied Industries Exposition. This lightweight spot welding gun uses a $^3/_{32}$-in. nonconsumable thoriated tungsten electrode and an inert

Close up of Aircospot Gun

gas shield. It makes instantaneous welds on stainless steels, mild steels and alloy steels, without the aid of jigs or fixtures.

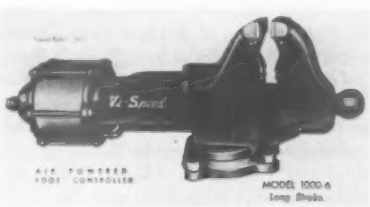
The Aircospot unit, which spot welds by making contact with only one side of the work, consists of a hand gun, control panel and all the necessary hose and cable assemblies. In order to use this equipment, a standard d-c power source, either a motor generator set or a rectifier type of machine, is required. The gun is water cooled, and used helium or argon, or a mixture of the two, for a shield. High frequency is not required. The Aircospot gun is rated at 250 amp and welds may be made on sheet steel up to $^1/_8$ in. in thickness and on stainless up to $^3/_{32}$ in. in thickness. The bottom section can be of greater thickness. In most cases, a backing plate is unnecessary.

The operator needed only position the top sheet on the piece to which it is to be joined, position the gun and pull the trigger. The operation is completed in just about one second.

Combination Air Vise

Vi-Speed Model 1000-6, long (6-in.) stroke, Combination Air Vise is a very heavy duty unit for conventional holding with 6-in. jaw faces, plus removable pipe jaws located in the lower portion of the jaws. The hardened pipe or "V" jaws are easily removed for replacement with the same or other types of fixtures converting this unit into a versatile all-purpose vise and press.

Jaws open to 11 in. and will hold up to 6-in. diam material in the "V" jaws. It



is powered with the proved Vi-Speed 8-in. air cylinder, 50:1 ratio, on any line pressure to 150 psi. The air stroke is completely adjustable from 0 to 6 in. This unit is mounted on a swivel base and is complete with all controls including positive safety features.

They are fully tested, guaranteed and available for a 30-day trial without obligations. Write for free catalog, or telephone manufacturer collect: Van Products Co., 3788 W. 12th St., Lakewood, Erie 2, Pa.

Fleetwelder Special

The Lincoln Electric Co., Cleveland, Ohio, has announced an a-c type welder, the Fleetwelder Special. The machine is available in 300, 400 and 500 amp, NEMA rated, sizes. It is a heavy-duty a-c welder for production welding.

The Fleetwelder Special is used for a wide range of a-c welding production jobs. It has a free circuit reactor control of welding current, separate from the main transformer which can be adjusted continuously through a wide range of currents. The control is also sensitive to a wide range of welding conditions and highly responsive to changing arc conditions. The machines are equally adaptable to sheet steel or heavy plate.

The machine is built for heavy duty—frame, core and case are welded steel; copper windings have spun glass, refined asbestos and mica insulation and mica coil separators. The current control mechanism operates through a double reduction gear drive with a ball bearing shaft to permit rapid current selection with ease and and trouble-free operation. The unit can be supplied with or without power factor correction. It has a high inbuilt power factor so that fewer capacitors are necessary. Three wheeled undercarriage for probability is optional equipment.

For additional information write to manufacturer at above address.

NEW LITERATURE

Welding Reclamation Leaflet

A new leaflet on reclaiming worn motor support bearings is being offered by Air Reduction.

The leaflet tells how a large western railroad solved the problem of repairing these hard-to-handle Diesel parts by using Airco No. 19 lead bronze electrode. Previously, the answer had been to scrap any bearing that had received a maximum lateral wear of $^3/_{16}$ in.

For complete details on how one company solved the problem, request a copy of this leaflet by writing to Air Reduction Sales Co., 60 E. 42nd St., New York 17, N. Y.

Small Production Bench Welder Bulletin

Bulletin 2100, just published by the Universal Welder Corp., 2557 E. 79th St., Cleveland 4, Ohio, lists complete data on the company's line of air-operated bench press welders for spot welding toys, electronic and radio assemblies, automotive and other similar parts.

The bulletin describes the 5, 10, 20 and 30 kva machines, specially designed for unusually high production rates by reason of low-inertia moving parts and short working strokes.

Complete dimensions, operating data and control detail is given for each of the machine sizes by the bulletin, available on request to the company.

Regulators

A 4-page folder on New K-G Regulators has been released by the K-G Equipment Co., Inc., 1744 Lehigh St., Allentown, Pa. The folder is available from the manufacturer on request. All inquiries should be forwarded to Karl H. Schmuldt, General Manager, K-G Equipment Co., Inc., P. O. Box 538, Allentown, Pa.

Flow Control Valves

A new four-page, two-color $8^1/_2$ by 11-in. bulletin (53-35) describing Vickers "Microfeed" flow control valves for machine tool and welding machine oil hydraulic systems is now available from Vickers, Inc., 1400 Oakman Blvd., Detroit 32, Mich.

Flow control circuits, performance curves, installation data and complete specification tables are given in the bulletin. Gasket-mounted valves in a series of models for $^1/_4$-, $^3/_8$-, $^3/_4$- and $1^1/_4$-in. standard pipe sizes are described, which provide adjustable metered flow capacities from 5 cu in. per min to 65 gpm. Also discussed are $^1/_4$-in. size valves with integral check valve for reverse free flow.

Eutectic Welding Design Manual

A new, fully illustrated manual is announced by the Eutectic Welding Alloys Corp., Flushing, N. Y., entitled *Manual of Design and Welding Engineering.*

It is a pocket-sized, 14-page booklet, and contains detailed instructions upon joint design with many drawings showing the difference between good and bad design. It shows the types of joints possible, their names and when and why they should be used on a given operation.

A section is devoted to overlaying and hard surfacing. It shows how overlays should be applied and some of the parts which lend themselves to this technique. The best joint designs are shown for welding steel and the recommended torch rods or electrodes.

Finally, illustrations show inspection and control; how to judge the efficiency of a welded joint and why a badly designed joint could be expected to fail under service conditions.

Copies of this manual are available free of charge from the Eutectic Welding Alloys Corp., 40-40 172nd St., Flushing 58, N. Y.

Comparative Bridge Designs

Comparative Bridge Designs presents designs by leading bridge designers in the Unites States to illustrate how significant savings in material and money can be achieved through the use of welded design. Material presented in the book was edited by Prof. James G. Clark, University of Illinois, from designs entered in a recent bridge design award program sponsored by The James F. Lincoln Arc Welding Foundation of Cleveland, Ohio.

The designs presented are welded designs of comparable riveted bridges, either existing or proposed. In order to cover as many types of bridges as possible, important details have been selected from the outstanding entries in the award program and compares details of the welded and riveted designs. The original designer's comments are included to explain how the welded designs realize important savings in material and time.

Major types of bridges in varying lengths are studied: continuous girder bridges, with and without floor beams; prestressed girder bridges; simple beam spans; simple trusses; continuous trusses; arches. Major design elements from a number of bridges of each type are described. Original drawings by the designers are reproduced in legible two-page size, along with the designer's discussion and description.

Stiff board, cloth covered binding, gold embossed; 211 pages; price $2.00 in USA; $2.50 elsewhere, postage prepaid. The James F. Lincoln Foundation, Cleveland, Ohio.

Ceramic Coatings for Metals

A new brochure describing ceramic coatings for protecting metals has been published by Solar Aircraft Co., San Diego, Calif. The booklet covers the uses and properties of Solaramic coatings, a family of proprietary ceramic coatings specially designed to protect high- or low-alloy steel fabrications from heat or corrosion.

Featured in the brochure is an extensive check list of the properties of Solaramic coatings under high temperature, medium temperature and corrosive service. Included is a listing of the basis metals to which coatings can be applied for various service conditions, and a check list of considerations in designing metal parts that are to be ceramic coated.

The booklet also contains a series of case histories showing how ceramic coatings have solved a variety of difficult metal service problems, as well as graphs showing typical oxidation rates based on temperature and length of service.

Copies of the new ceramic coating booklet are available from Solar Aircraft Co., Department 701, San Diego 12, Calif.

Heavy-duty Air Compressors

Joy Manufacturing Co., Henry W. Oliver Bldg., Pittsburgh, Pa., announces the release of a new 36-page Bulletin A-72 on Joy Series 100, Class WN-114 heavy-duty air compressors for industry. The bulletin contains complete information on construction and operation of the compressor. Illustrated therein are seven models of the compressor as a single unit for displacement capacities from 1186 to 1948 cfm as well as twin units which furnish up to 3896 cfm.

The Joy WN-114 is a two-stage, double-acting compressor of four-cylinder semiradial design. It is available with flange-mounted, V-belt or direct connected drive. Features include honed, replaceable crosshead and cylinder liners, patented "Dual Cushion" valves, and full force-feed lubrication.

1953 Supplements to Book of ASTM Standards

The American Society for Testing Materials has announced the availability of the 1953 supplements to their *1952 Book of ASTM Standards* which is issued triennially. Together with the big *Book of ASTM Standards*, they give in their latest form all of their specifications, tests, definitions, etc., excepting the chemical analysis of metals. They are issued in seven parts.

Additional information regarding these supplements may be obtained by writing to the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

NEMA Standard for Arc-welding Electrode Identification

The National Electrical Manufacturers Association has announced the availability of the revised standard entitled "NEMA Standard for Arc-welding Electrode Identification, Publication No. EW2-1954."

The tables in this publication identify arc-welding electrodes by the use of colors. They are based on a color system which permits the assignment of colors to new electrodes. The location of color markings is illustrated.

Copies may be obtained by writing to NEMA Headquarters, 155 E. 44th St., New York 17, N. Y. Price $0.70 per copy.

Tool Shape Identification Chart

An unusual "Carbide & Abrasive Tool Shape Identification Chart" is available free from the Metal Removal Co., Chicago. This helpful chart has illustrated in actual size the various shapes of the company's mounted points. Carbide burr shapes are also illustrated, with dimensions and prices listed as for the mounted points.

Along with this information are three tables presenting data on tap drills, twist drill and steel wire gage, as well as decimal equivalents.

The 35- x 24-in. chart is intended for mounting on the wall of a tool crib, stockroom, shop or office, serving as a ready reference.

For further information contact E. Michals, Metal Removal Co., 1546 N. Orleans St., Chicago 10, Ill.

Now—a new line-up of PAGE welding wire in coils, reels, packages

• Here are some of the ways PAGE welding wires are packaged to protect them during shipment and to make it easy for you to handle and stock them. Two new packages are Leverpaks and pallet-mounted coils.

LEVERPAKS • Here's one of the best containers for coils up to 16″ ID. It's light-weight, but durable. It is sealed air-tight and is packed with moisture-absorbing substance to reduce corrosion. Release safety catch, pull lever, and the whole top comes off. It's just as quickly resealed. Leverpaks can be rolled easily. They stack perfectly and take a minimum of floor space. They cost you nothing extra and have many re-uses.

PALLET-MOUNTED COILS • If you have a fork-lift truck, you'll like PAGE'S new pallet-mounting of 22″ ID coils. Steel strapping and paper wrapping protect coils and hold them securely. You can run them in and out of freight cars and trucks, and spot them in your plant.

AUTOMATIC WELDING WIRES • **Inert Gas** — Six PAGE-ALLEGHENY stainless grades in .035″, .045″, and .0625″ diameters. Precision thread-wound on 25-lb. non-returnable reels to fit popular arc welding machines. **Submerged Arc** — PAGE Stainless in wire diameters from 1/32″ to 5/16″, plain or copper coated. In layer-wound coils or 22″ or 24″ mill coils.

GAS WELDING RODS • In a variety of analyses: stainless, Armco, medium and high carbon, and manganese or naval bronze.

Warehouse stocks in Chicago, Denver, Houston, Los Angeles, San Francisco

Write our Monessen, Pa., office for literature and prices

ACCO
Page Steel and Wire Division
AMERICAN CHAIN & CABLE

Monessen, Pa., Atlanta, Chicago, Denver, Detroit, Houston, Los Angeles, New York, Philadelphia, Portland, Ore., San Francisco, Bridgeport, Conn.

GAS Automatic Arc

PERSONNEL

Salisbury Retires from Airco; Humberstone Named Successor

H. R. Salisbury, president of Air Reduction Sales Co., retired from that position on June 1, 1954, it has been announced by J. A. Hill, president of Air Reduction Co., Inc. He will continue as a director of Airco's foreign subsidiaries, Air Reduction, Canada Ltd. and Cuban Air Products Corp. J. H. Humberstone, president of the Ohio Chemical and Surgical Equipment Division of Airco in Madison, Wis., succeeds Mr. Salisbury. Mr. Humberstone is also vice-president of Air Reduction Co., Inc.

Mr. Salisbury came with Airco in 1926 and held various management positions in the company. Among them were manager of the sales office in Bettendorf, Iowa, and later assistant manager and manager of the Philadelphia, Pa., district sales office. In 1943 he was appointed special assistant to the president

H. R. Salisbury

as Airco's Washington, D. C., representative. He was named president of Airco Export Corp. in 1945 which later became Airco Company International. Mr. Salisbury was elected president of Air Reduction Sales Co. in 1949, a post he has held up to this time.

Mr. Humberstone, after being associated with the General Electric Co. for several years as an electrode development engineer, transferred to the Arcrods Corp. at the time of its formation.

After his wartime assignment as a research supervisor of the War Metallurgy Committee, Mr. Humberstone became director of research and welding

Joseph H. Humberstone

engineering for the Arcrods Corp. until 1946 when he was appointed vice-president in charge of operations.

In 1948 Mr. Humberstone accepted a position with Air Reduction as manager of apparatus production, and continued his association with Arcrods as a director, subsequently becoming president, and later, chairman of the board, which position he still holds. In 1950, Mr. Humberstone became president of Airco Equipment Manufacturing Division which he held until 1951, when he was elected to the office of vice-president of Air Reduction Co., Inc. In February 1953, Mr. Humberstone became president of the Ohio Chemical & Surgical Equipment Co. Division, a post he has held up to this time.

R. E. Lenhard, vice-president of Ohio Chemical and Surgical Equipment Co., succeeds Mr. Humberstone as president of that division.

Personnel Promotions

W. E. Noyes, vice-president in charge of sales for the Diversey Corp., Chicago, announced the promotions of five men to new key sales positions within the Diversey sales department.

R. J. Stell was named manager of new product development, a newly created position; C. R. Reid was promoted to assistant general sales manager; E. M. Petrie has been appointed manager of Diversey's Technical Service Department; M. J. Butler, Jr., was named advertising-sales promotion manager; and H. M. Pickles, Jr., has been appointed assistant to Vice-President Noyes.

The moves were said by Mr. Noyes to be part of the Company's aggressive plans for expansion in present and new markets. Diversey manufactures, among other products, pre-finishing cleaners and etchers for the metal industries.

Mochel ASTM President

Mr. Norman L. Mochel, manager of Metallurgical Engineering, Westinghouse Electric Corp., has been elected president of the American Society for Testing Materials for the 1954–55 fiscal year.

A native of Pittsburgh, Mr. Mochel was first employed in his home city in the Inspection Department of the then Westinghouse Machine Co. He became responsible for the work of testing materials and has for many years held his present position as Manager of Metallurgical Engineering, Westinghouse Electric Corp., Lester Branch.

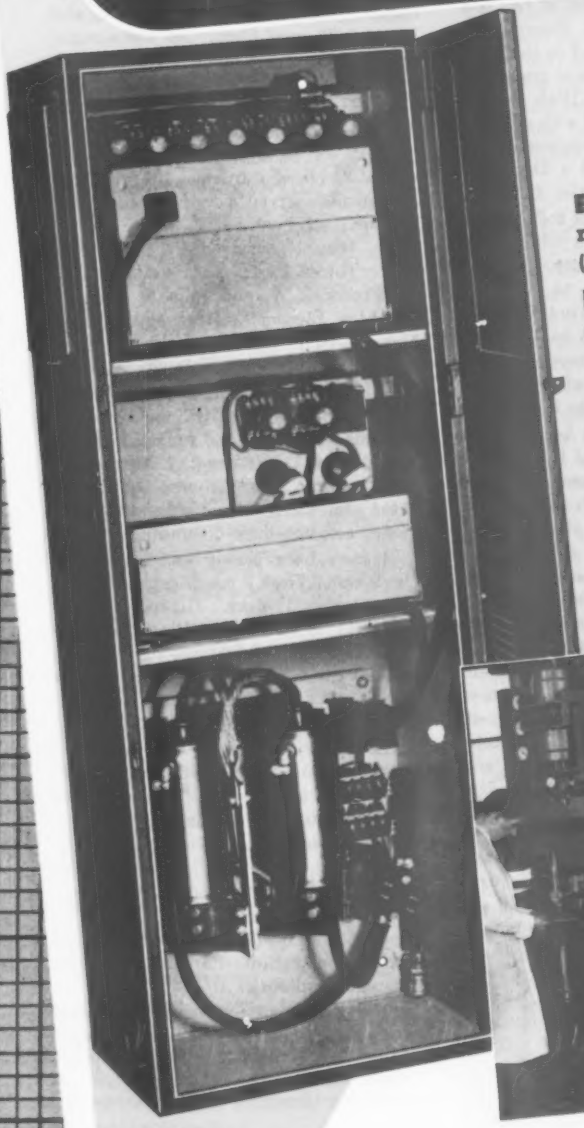
Mr. Mochel has a long and intensive record of service in ASTM, was a director for two separate terms, and vice-president 1952–54. For 15 years he was chairman of Committee A-1 on Steel; he was also for several years chairman of the joint ASTM-ASME Committee on Effect of Temperature on Properties of Metals in which he is still very active. He is a member of the ASTM Ordnance Advisory Committee. Among other ASTM activities he represents his company on Committees A-1 on Steel, A-10 on Iron-Chromium-Nickel and Related Alloys, and B-5 on Copper and Copper Alloys, Cast and Wrought.

During World War I, Mr. Mochel saw service overseas with the Engineers Corps., and in World War II rendered invaluable service in a civilian capacity to several branches of the Government and the Armed Forces. One of his outstanding contributions was to the National Emergency Steel Specification work.

He has written numerous technical papers, one of which "The High Temperature Fatigue Strength of Several Gas Turbine Alloys" co-authored with P. R. Toolin, won the 1948 ASTM Charles B. Dudley Medal for the outstanding paper on research in engineering materials. In 1952 he presented the first H. W. Gillett Memorial Lecture at the ASTM 50th Anniversary Meeting on the subject

Stainless Steel? Aluminum? Magnesium? Air-Hardenable Steels? Low Carbon Steels? Aluminum-Magnesium Alloys?

What's Your Precision Welding Problem?



Square D has the control to meet your exact needs!

Easier maintenance Vastly simplified circuits require fewer tubes and only one operating relay (for the air valve).

Increased dependability Components designed specifically for industrial welder service. Tube circuits are fail-safe. Initiating contacts are in isolated 24-volt circuit.

Consistent accuracy Regulated DC voltage on tube control grids compensates for supply fluctuation or tube variations.

Greater accessibility Timer, heat control, up and down slope, forge and chill temper panels—all are designed for easy inspection and maintenance, with quick fasteners and plug connectors.

Thomson Electric Welder Company Puts Square D Control to "Acid" Test

• This Thomson Welding Machine is used for experimental and "special" jobs in the Thomson laboratory. It has put Square D control to the "acid test" in scores of precision operations. It has made crack-free welds in a variety of aluminum alloys in gauge thicknesses up to .072". It has made excellent welds in air-hardenable steels and in ½" diameter steel bars.

Write for Bulletin 8993. Address Square D Company, 4041 N. Richards Street, Milwaukee 12, Wisconsin. Or consult your nearby Square D Field Engineer.

SQUARE D COMPANY

"Man, Metals, and Power"—this Lecture commemorates Dr. H. W. Gillett, one of America's leading pioneer metallurgists.

His other memberships include AMERICAN WELDING SOCIETY, American Society of Mechanical Engineers, American Society of Naval Engineers, American Society for Metals, American Institute of Mining and Metallurgical Engineers, The Franklin Institute, Iron and Steel Institute (England) and Institute of Metals (England).

Constantine Appointed Plant Manager

Leonard R. Constantine has been appointed Plant Manager of the Catasauqua, Pa., plant of the Fuller Co., according to C. O. Davis, General Manager.

The Fuller Co. designs and manufactures pneumatic conveyors, heat recuperators, rotary compressors, and vacuum pumps, principally for the cement, heavy chemical and food industries.

He graduated from Lehigh University in 1943, and was employed as a Junior Engineer with the Dravo Corp., of Wilmington, Del. From 1945 to 1947, he was Assistant Welding Engineer for the M. W. Kellogg Co.; and was then appointed to the position of Welding Engineer for the Elliott Co.

Mr. Constantine is an active member of the AMERICAN WELDING SOCIETY, and was elected as Chairman of the Pittsburgh Section for 1954.

Clarke Promoted

Announcement of the appointment of Frank T. Clarke as Manager of Sales of American Steel & Wire Division's District Sales Offices in Boston was made by Ross F. Curtis, Eastern Area Manager of Sales of this United States Steel unit.

Born in 1901 in Boston, he was graduated from Dorchester High School in 1918. He joined American Steel & Wire there in 1921 as an office assistant in the warehouse. He held various posts as clerk and correspondent in the warehouse until 1930 when he was promoted to salesman in the Manufacturers' Department. In 1940, he was transferred to the New York City Sales Offices as Assistant Manager in the same Department. He spent the war years heading up the Division's Washington Office, handling products for the war effort.

Promoted to Director of Cold Rolled Strip Sales in 1947, he spent the following two years in Cleveland. In 1949, he was named Manager of Manufacturers' Products in New York—the last position he held at the time of his elevation to Manager of Sales in Boston.

He is a member of the *AWS*, Bankers' Club and Baltusrol Country Club.

OBITUARY

Dr. Wendell F. Hess

Dr. Wendell F. Hess, 51, director of research at Rensselaer Polytechnic Institute, Troy, N. Y., and head of the Department of Metallurgical Engineering, died suddenly April 21st. He was one of the world's leading authorities on the scientific aspects of welding.

Dr. Hess's death was termed a "great shock and tremendous loss to the Institute and his field of study" by Rensselaer officials.

Born Jan. 1, 1903, the son of the late Wendell, Jr., and Anna M. Beiermeister Hess, Dr. Hess was educated in the Troy public school system. He was graduated from School 16 and Troy High School. He was graduated from RPI with a bachelor's degree in electrical engineering in 1925. In 1928 he received a Doctor of Engineering degree from the Institute.

He became a member of the RPI faculty in 1928—the beginning of a relationship that was to last until his death. He was promoted from instructor to assistant professor in 1930 and served in this capacity until 1938. From 1938 to 1945 Dr. Hess was an associate professor and head of the welding laboratory, before his promotion to full professor in the latter year.

Dr. Hess was appointed head of the Department of Metallurgical Engineering and Robert W. Hunt Professor of Metallurgical Engineering in 1947, and in 1953 was named to the position of director of research for the Institute.

An internationally recognized figure in the welding field, the teacher-researcher had written more than 50 scientific papers in the field of electric arc and resistance welding of steels, aluminum, magnesium and nickel alloys. Some of his most comprehensive research studies were on spot welding of hardenable alloy steels; measurement of arc weld cooling rates, and flash welding of aluminum alloys.

The awards he received for his work were numerous. He received among others the Lincoln Gold Medal of the AMERICAN WELDING SOCIETY in 1944; the University Award of the Resistance Welder Manufacturers Association in 1944, 1945, 1947 and first and second prizes in 1948; the American Iron & Steel Institution Medal in 1944, and the John Price Wetherill Medal of the Franklin Institute in 1948.

Dr. Hess was active in many professional societies and organizations. He was a member of Sigma Xi and Tau Beta Pi Fraternities, a past national president and former board of directors' member of the AMERICAN WELDING SOCIETY, a fellow of the American Institute of Electrical Engineers, and a member of the American Society for Engineering Education, American Society for Testing Materials, American Society for Metals, American Institute of Mining & Metallurgical Engineers and Franklin Institute.

Dr. Hess served the SOCIETY long and well. He became an Associate Member in 1929, a Member in 1938 and was made an Honorary Member in 1948. He was Chairman, Northern New York Section; District Vice-President, New York and New England; National 2nd Vice-President, 1944–45; National President 1945–46; Member of Board of Directors, 1944–49.

The RPI professor was also a research consultant for Babcock and Wilcox Co. Previously he had been retained as a research consultant by American Bureau of Shipping, International Nickel Co. and Metal & Thermit Corp. He was a registered professional engineer of New York State.

Dr. Hess was a member of the 5th Ave.-State St. Methodist Church, Troy, and had served for many years as chairman of its board of trustees. At one time he had also served as superintendent of the Sunday School.

Dr. Hess is survived by his widow, Grace Towne Hess; three sons, Wendell T., Frederick W. and John R. Hess; a daughter, Eleanor S. Hess, and a sister, Mrs. Alfred E. Blake of Caldwell, N. J.

A touching tribute to Dr. Hess is paid by a colleague, Dr. Matthew A. Hunter, dean emeritus of the RPI faculty, who, since his retirement, had worked with Dr. Hess in the Department of Metallurgy. His statement is an eloquent summation of the admiration of Dr. Hess and the deep sorrow occasioned by his untimely death.

"I have been closely associated with Dr. Wendell Hess through every stage of his professional career. His success in his studies in his undergraduate and graduate years had already forecast for him the brilliant career which he displayed in later years.

"He was regarded as an administrator of the highest rank in his work as head of the Department of Metallurgical Engineering and more recently as head of the research activities of the Institute.

"He gained national recognition as the outstanding leader in research in the scientific aspects of welding operations. His all too early death will be mourned by all of his professional associates. In his passing the institute has lost one of its outstanding alumni.

"His monument remains in the hearts of students who were privileged to enjoy an association with him."

The family of Wendell F. Hess wishes to express thanks to the great number of his friends who offered kindnesses and sent messages of sympathy and condolence following his death on April 21.

WIFE, SONS, DAUGHTER

SECTION NEWS AND EVENTS

as relayed to C. M. O'Leary

Election of Officers

Bethlehem, Pa.—The following officers and directors have been elected by the *Lehigh Valley* Section for the 1954–55 season:

Chairman—R. E. Somers, Bethlehem Steel Co., Bethlehem, Pa.

1st Vice-Chairman—V. P. Edwards, Ingersoll-Rand Co., Phillipsburg, N. J.

Secretary-Treasurer—R. A. Bartholomew, Lehigh Structural Steel Co., Allentown, Pa.

Directors—C. L. Seifert, Ingersoll-Rand Co., Phillipsburg, N. J., and J. L. Walmsley, Bethlehem Steel Co., Bethlehem, Pa.

Social Meeting

Boston, Mass.—The Third Annual Social Meeting of the *Boston* Section was held on May 24, 1954, at the South Shore Country Club, Hingham, Mass.

One hundred and seventy-five members and guests attended, many of whom took part in the various sports events that were held during the day. Prizes were awarded for the several competitions as follows:

Golf (Kickers Handicap):

Low Gross, 75	James Swim
Low net, 67	Thure Johnson
Kickers first net	J. C. Grant
Kickers 2nd net	James Beaton
Kickers 3rd net	Ralph Bonin
High gross	Mick Metrick

Horeshoe Pitching: John and George Sherman

Bowling:

High three strings, 334	Herb Smith
Best three consecutive, 323	Al Barilaro
High single, 126	Tom Walsh

At about 7:30 P.M., another one of Dora Ferguson's excellent roast beef dinners was served, followed by a drawing of nearly one hundred door prizes. During and after the dinner, musical entertainment was provided; it was eminently suited to this type of stag party.

Consultation Night

Buffalo, N. Y.—The final meeting of the *Niagara Frontier* Section for the season was held on May 28th at the Hotel Sheraton. There was no formal speaker. The meeting was in the nature of a consultation night with moderator, Charles H. Jennings. It was an open night. Everyone was invited to ask questions based on their own welding problems and to answer questions raised by others.

The elected officers and directors for the 1954–55 season were announced.

Beer and pretzels were served as a farewell to a very successful season.

The meeting, while not well attended due to the lateness of the season, was nevertheless very enthusiastic and was very much enjoyed by all those who were present.

Radiographic Inspection

Chicago, Ill.—The *Chicago* Section has for years held their meetings either in the Loop part of Chicago or in close proximity to that section because of easy accessibility from all sections of the city. It was felt that there were many interested in welding located in Lake County, Indiana, which mainly includes Gary, Hammond, Whiting and East Chicago. Therefore, the April 9th meeting was held in that area at Vogels Restaurant, where a family style dinner was enjoyed. There were 159 at dinner and 178 at the meeting.

William Lowry, President, Hammond Chamber of Commerce, gave an interesting talk on the importance of Lake County to industry and all peoples of the country. It is the largest steel producing section in the world and also the largest gasoline and allied products producing area in the world.

R. E. Lorentz, Jr., AWS the technical speaker, gave a most interesting talk, accompanied by slides, on the part that radiography plays in weld inspection and control. He discussed reasons for the use of radiography, types of joints amenable to radiography, types of defects it will show, technical details, code requirements, and limitations of radiographic inspection for certain types of welds and certain defects.

The question-and-answer period following the speaker's lecture brought out many extra details not covered by the talk with most of the questions pertaining to the mechanics of materials and methods in radiography.

This was the most successful meeting of this type held in a long time by the Chicago Section. Since this meeting was planned and arranged for by Ralph Gaedtke, AWS of the National Cylinder Gas Co., its success can be largely attributed to his untiring effort and planning.

Plant Tour

Cincinnati, Ohio.—The April 27th meeting of the *Cincinnati* Section was in the form of a tour of the plant of Hobart Brothers, Troy, Ohio. This was of much interest to those who wished to see welding machines made and electrode extruded on the latest equipment.

The group was broken up into smaller groups and conducted through the machine division and then the electrode plant. By breaking up into small groups, each individual was able to ask and receive answers to questions they might ask.

After the plant tour, the Hobart Brothers Co. sponsored a very pleasant meal. At the conclusion of the meal, J. Blankenbuehler, AWS, gave a pep talk on the advantages of the AWS and asked the members to intensify their membership campaign.

Stainless Steel

Dallas, Tex.—The regular monthly dinner meeting of the *Dallas* Section was held on April 28th at the Delta Restaurant. "The Welding of Stainless Steel" was very

April 9th Meeting Chicago Section

for high conductivity forgings and castings for resistance welding....

Specify WW

Seam Welding Wheels
Bushings • Knees
Shafts • Spindles
and other
current-carrying parts

Long, specialized experience with welding requirements establishes WW as a leading reliable source of high conductivity, high strength forgings and castings—in rough or finished form. Add to this experience WW's participation in Fansteel's continuous metallurgical research. Count on WW for the right alloy every time. WE MAKE THEM OURSELVES, WE KNOW THEY'RE RIGHT.

YOURS
Without Obligation
... this informative technical catalog. Write today.

WW ALLOYS, INC.

W544C

Division of Fansteel Metallurgical Corporation
11644 Cloverdale Ave. • Detroit 4, Michigan

ably discussed by Harry F. Reid, [AWS], Manager, Technical Services Division, McKay Co., York, Pa. Mr. Reid used slides to illustrate his talk.

Plant Tour

Dayton, Ohio.—The May meeting of the *Dayton* Section, held on the 11th, consisted of a plant visitation to the Aeroproducts Corp., Allison Division of GMC at Vandalia, Ohio. Approximately 97 members and their guests showed up for this tour.

Chairman Glyn Williams held a short business meeting preceding the tour at which L. P. Marking reported on the outcome of the Indianapolis Quiz. The Dayton team was made up of Leroy Aiken, Tom Falter, Bob Appenzeller and Wil Khkola. The team placed second, just behind Fort Wayne. Mishawaka was third and Detroit fourth.

The tour began with an impressive flash welding demonstration which required 5¼ min. This was used in the fabrication of the large paddle-type blades that are being manufactured for the C-119. After this demonstration, the group was broken down into small groups of ten and taken through the entire plant. The following operations were viewed: forging of the blades, root machining of them, the contouring operation on the planers, removal of the excess stock, grinding of the blade to meet the various thickness and contours required, brazing, heat treating, machining, balancing, plating and painting.

Of particular interest was the prop pitch controls which are installed in the hub before the blades are inserted.

Besides making propellers for the C-119, the group was also shown props that were being produced, both the 3- and 4-bladed variety, for various fighters and turbo jets. The tour was climaxed by the visit to the building in which all the new props are tested. After this, refreshments were served to the group and the meeting was adjourned.

Nondestructive Testing

Denver, Colo.—The May meeting of the *Colorado* Section, and last for the present season, was held in the Festival Room of the Oxford Hotel on May 11, 1954.

Following refreshments and an excellent dinner, Lloyd J. Oye, Assistant General Sales Manager of the Magnaflux Corp., gave a talk on "Nondestructive Testing" which proved very interesting as well as educational.

The result of the recent ballot was announced and the following officers were installed:

Chairman—D. C. Card, President, C. S, Card Iron Works Co.
1st Vice-Chairman—C. Brinton Swift, Linde Air Products Co.
2nd Vice-Chairman—S. Rodda, General Iron Works
Secretary-Treasurer—Carl Ditson, Stearns Roger Manufacturing Co.

Welded Steel Tubes

Detroit, Mich.—On Mar. 12, 1954, the *Detroit* Section was fortunate in having an outstanding speaker covering an extremely interesting and difficult subject.

The history and development of welded steel tubes was presented by Richard O. Berg, Vice-President in Charge of Research, Michigan Steel Tube Products Co. His illustrated talk was entitled "The Leading Role."

E. Dombroski, Chief Engineer, Michigan Broach Co., was the dinner speaker and presented a thumbnail sketch of "City Government."

Quiz Night

Detroit, Mich.—The annual "Quiz the Experts" meeting of the *Detroit* Section, was, as always, a well attended and highly entertaining meeting.

The Sections competing were: Indiana, Anthony Wayne, Toledo and Detroit. Hats off to the winners: Indiana Section! The importance and value of "Quiz the Experts" type program cannot be overestimated, and the large attendance (138) proved its value.

J. Philip Martin of the Ford Motor Co., Community Relations Division, presented a review and discussion on "Community Relations."

Ladies' Night

Erie, Pa.—The annual Ladies' Night meeting of the *Northwestern Pennsylvania* Section was held on May 11th at the G. E. Community Center and, as usual, it was nontechnical.

Merle Grimler, of General Electric Co., gave a very amusing Chalk Talk, illustrated with cartoons of a lighter view.

Max Darone, General Secretary of the YMCA, gave one of his famous talks on music.

Plant Tour

Houston, Tex.—On April 29th, following a delicious barbecue, 150 members and guests of the *Sabine Division* of the Houston Section made a tour of the Consolidated Western Steel's Pipe Mill, plate shop, machine shop and structural shop conducted by Glenn Martin, Assistant Superintendent of Consolidated. The members and their guests saw semi- and fully automatic welding equipment used in the fabrication of high-test pipe, plate structures and structural steel. Linde and Lincoln Twin-Arc machines were shown in operation along with all types of special jigs, fixtures and positioners. The tour was highly interesting and informative and was

very enthusiastically received by all the members and visitors. The entire plant tour and barbecue was very well planned by the Consolidated personnel with no cost to the Section.

Low-Alloy Steels

Houston, Tex.—N. C. Jessen, AWS, of the Babcock and Wilcox Co., Barberton, Ohio, presented an excellent semitechnical discussion on the subject "Welding of Low-Alloy Steels with Low-Hydrogen Electrodes" at the April 28th dinner meeting of the *Houston* Section held at the Ben Milam Hotel. Mr. Jessen's discussion covered the development as well as the various types of weld rods and their application to alloy steels.

Through the courtesy of the Western Auto Stores, an excellent sound color film entitled "Fishing in the Everglades" was shown and enjoyed before the meeting.

High-Temperature Alloys

Long Beach, Calif.—Francis H. Stevenson, AWS, Production Engineer—Welding, Aerojet-General Corp., presented an excellent technical address on "Welding of High-Temperature Alloys Used in Rockets" at the April 16th dinner meeting of the *Long Beach* Section held in Miller's Restaurant.

Welding Procedures

Long Beach, Calif.—Fifty-four members of the *Long Beach* Section heard Robert Welch of the Eutectic Welding Alloys Corp., give a talk on "New Welding Procedures" at the March 19th dinner meeting held at Miller's Restaurant.

Election of Officers

Los Angeles, Calif.—The *Los Angeles* Section announces the election of the following officers:

Chairman—S. R. Lanier, Southwest Welding & Mfg. Co., Alhambra, Calif.
Vice-Chairman—Francis V. McGinley, Victor Equipment Co., San Francisco
Secretary—C. B. Smith, Douglas Aircraft Co., Long Beach

Election of Officers and Lecture

Los Angeles, Calif.—The May meeting of the Aircraft and Rocketry Welding Panel of the *Los Angeles* Section was held on May 6th at Swally's Key Club.

A report on the election of new officers was made as follows:

PANEL OFFICERS:

Chairman—Dick Hayes, Douglas Aircraft Co., Long Beach
Vice-Chairman—H. L. Meredith, rth American Aviation, Downey
Secretary—Arthur Wynn, Harnischfeger, Lynwood
Membership—John Wiley, Los Angeles

PANEL EXECUTIVE COMMITTEE:

Inert Arc—Byron Russell, Airline Welding, Inglewood
Metallic Arc and Gas Welding—Leo West, Douglas Aircraft Co.
Spotwelding—Dennis Samuelson, Solar Aircraft Co., San Diego
Flashwelding—Mario Ochieano, Lockheed Aircraft Co., Burbank
Automatic Processes—John Arthur, North American Aviation, Inc., Downey
Production Development—Jim Hurzeler, North American Aviation, Inc., Downey
Codes and Specification—E. Patrick Deason, Aerojet-General Corp., Azusa
Metallurgy—Frank Alleash, Convair, San Diego
Process Development—Bob Hay, Linde Air Products, Los Angeles
Inspection—John M. McBride, Tujunga Calif.

Th el hit the jackpot with another "first" in current research and development promulgation of a very wonderful but tricky super airframe material; namely, 17-7 Precipitation Hardening Corrosion Resisting Steels (CRES).

At this same meeting, C. W. Funk, metallurgist for Aerojet-General Corp. presented a very interesting talk on "The Metallurgical Aspects of Welding Precipitation Hardening Stainless Steels." The paper is co-authored by W. J. Branger, also metallurgist at Aerojet-General Corp.

Welds made in 17-7 pH CRES sheet material by inert arc welding were physically tested in the as-welded, annealed and heat-treated condition.

Mr. Funk found that improper inert gas shielding of the solidifying weld resulted in a loss of carbon and aluminum in the weld deposit. This loss is detected in form of a white slag residue on the weld bead. The slag contains as much as 22% aluminum.

Further tests revealed that a hard zone was found adjacent to the weld. It was the authors' combined opinion that the hard zone was caused by chromium carbide precipitation.

The heat treatment of welded 17-7 pH parts requires a 1900 ± 25° F solution anneal. Mr. Funk suggested that weldments be annealed in dry hydrogen or crack ammonia controlled furnace atmospheres.

The transformation heat treatment of 1400° F for 90 min should be followed by a rather rapid air cool to below 60° F. Other sources recommend within 1 hr.

Also important is a close check on the chemical analysis. The amount of aluminum appears to be a critical factor.

Inspection Techniques

Louisville, Ky.—Lew Gilbert, AWS, Executive Editor of *Industry and Welding Magazine* and *Industry and Welding Quarterly*, spoke on the subject "Inspection Techniques for Quality Welding" at the April 27th dinner meeting of the *Louisville* Section held at Korfage's Tavern. Mr. Gilbert pointed out some of the various techniques that are being used and described their adequacies. He touched on some of the latest developments such as ultrasonic testing and its possible future in the weld testing field.

Plant Tour

Midland, Mich.—About 100 members and guests of the *Saginaw Valley* Section, toured the Dow Chemical Co.'s boiler shop and power house on Thursday evening, May 13th, at Midland, Mich., to see the shop's welding facilities and witness demonstrations on steel tank welding, magnesium welding and other production setups. The new boiler shop and its welding facilities was the center of attraction for all tourists.

After the hard-legged tour, the group met in the cafeteria where refreshments were served with the compliments of the Dow Co. After everyone had their fill, the group assembled in the auditorium to watch the colored movies on the Rose Bowl football game and parade, which was narrated by Bob Devaney—end coach of Michigan State.

This tour climaxed a very successful 1953–54 season for the Saginaw Valley Section, which could not have been made possible without the sincere efforts of everyone concerned. Much credit is due to Past-Chairman Malcolm Blackwood for the splendid and sincere guidance he gave the Section throughout the season.

Automatic Arc Welding

Peoria, Ill.—The regular monthly dinner meeting of the *Central Illinois* Section was held on April 21st at the New Sazarac. A discussion of the present methods of semi- and fully automatic welding with the projected development trend toward future use of equipment and application was covered by H. M. Downing, AWS, Chicago District Manager, Lincoln Electric Co. An interesting discussion period followed.

H. R. Baldwin, Process Engineer, Le Tourneau-Westinghouse Co., was technical chairman of this meeting.

Tri-State Conference

Pittsburgh, Pa.—The final meeting of the 1953–54 Season of the *Pittsburgh* Section, climaxed with the Seventeenth Tri-State Annual Conference and Ladies Night, was held on Friday evening, April 23rd, in the Webster Hall Hotel, Oakland, Pittsburgh, Pa.

Edward W. Moles (left) being congratulated by J. H. Humberstone, AWS Vice-President, upon being installed as Chairman of the Long Island Division of the New York Section. Looking on is Robert Platz of the Long Island Division By-Laws Committee

Three hundred forty-nine members, guests and their ladies were in attendance and were treated to a splendid dinner of prime ribs of beef and lobster-tails with all the trimmings.

Following the dinner short talks were given by President F. L. Plummer, District Director John H. Blankenbuehler, of the Fourth District, and J. H. Strickler, Senior Vice-President of the Engineers Society of Western Pennsylvania.

Past Chairman G. O. Hoglund, Welding Engineer of the Aluminum Company of America, acted as Toastmaster for the occasion and introduced in turn all of the new incoming elected officers for the 1954–55 Season, the executive officers and invited guests.

Retiring Chairman W. H. Kauffman presided in his usual efficient manner welcoming the many members and guests and thanking them for their cooperation during his term in office.

The affair closed with entertainment provided by the Radio Artists Entertainment Service and the drawing of many beautiful and expensive door prizes.

Training Welding Operators

Portland, Ore.—The 7th and last meeting of the current season of the *Portland* Section was held on Tuesday, May 11th at the Heathman Hotel. Dinner followed a social hour of refreshments and good fellowship. Following dinner, announcement was made of the annual election of officers for the forthcoming season as follows:

Chairman—B. N. Wood, Metallurgical Engineers, Inc.
Vice-Chairman—F. M. Parker, National Cylinder Gas Co.
Secretary—G. A. Conner, Williamette Iron and Steel Co.
Treasurer—S. W. Georgeson, Air Reduction Pacific Co.
Executive Committee—Leroy J. Schmid, American Pipe and Construction Co.

The speaker of the evening, William H. Rice, on sabatical leave from Oklahoma A&M College, presented a most informative and interesting talk on "The Use of Motion Pictures in Training Welding Operators." Mr. Rice's talk was accompanied by a film.

The membership of the Portland Section has increased from 45 to 59 this season—a very nice increase. Monthly turnouts this year have been unusually good and the Section hopes to continue this trend.

At the close of the meeting, B. N. Wood presented the outgoing Chairman, Stan Richardson, with a remembrance and thanks in the form of a "Past-Chairman pin," duly engraved.

The retiring Secretary, F. M. Parker, extends his thanks to all those who cooperated with him in his very pleasant work.

Submerged Arc Welding

St. Louis, Mo.—The regular monthly dinner meeting of the *St. Louis* Section was held on April 9th at the Forest Park Hotel with an attendance of 65 at dinner and 80 at the meeting.

Speaker was Perry C. Arnold, AWS, of the Chicago Bridge and Iron Co. Mr. Arnold first gave the history of the use of submerged arc welding in the field by Chicago Bridge and Iron Co. He stated that they started using it in the field about 1939 on small vessels that could be put on rollers. About 1940 or 1941 they began to use multipass submerged arc welding, which enabled them to weld steel up to 4 and 5 in. thick. In 1948, 1949 and 1950 they learned how to weld spherically dished plates automatically, by means of positioners which tilt the welding head to keep it in the proper position relative to the weld.

The movie was a sound, color film which depicted the erection of the 225-ft diam sphere at Milton, N. Y., which was built for General Electric for the Atomic Energy Commission. It was used to shield Nuclear Reactors being developed for use in atomic submarines. This sphere is designed for 20 psi, and is the world's largest pressure vessel. Twenty-six thousand feet of welding were performed in the erection of this sphere, approximately 15,000 ft of which were done on the ground by submerged arc autowelding, by means of giant welding positioners. All welds were 100% X-rayed, and the sphere was tested with air pressure upon completion. One-inch steel plate was used, of A-201 Grade B firebox quality, in accordance with A-300 Specification.

Mr. Arnold said that his organization is finding the dual-arc or twin-arc process very useful, and he predicted that it will be more so in the future. By using two or three $^1/_8$ or $^5/_{32}$-in. electrodes in the same weld puddle, welds with superior impact properties, and low porosity and slag, are produced.

The talk and movie were enjoyed by all, and of course were of particularly great interest to those engaged in steel plate erection.

Election of Officers

Seattle, Wash.—The *Puget Sound* Section announced the election of the following officers for 1954–55:

Chairman—L. B. Zylstra, Instructor, University of Wisconsin
1st Vice-Chairman—R. A. Kamb, Arcweld Manufacturing Co., Inc.
Secretary-Treasurer—D. H. Thorpe, Linde Air Products Co.

Field Trip

Seattle, Wash.—On May 13th, 64 members and guests of the *Puget Sound* Section took part in a field trip through the plant of the Pacific Car and Foundry Co. Structural Division. C. M. Styer, AWS, and R. Herman, AWS, explained the various welding problems encountered and how they are overcome in their plant. A thoroughly interesting and informative time was enjoyed by all.

Annual Meeting

South Bend, Ind.—The *Michiana* Section held its annual meeting and social evening on Thursday, May 20th, at the Chain-O-Lakes Conservation Club House

near South Bend, Ind. After reports of the Secretary and Treasurer had been read and approved, the following officers were elected for 1954–55.

Chairman—Donald Kyler, Miles Laboratories, Inc., Elkhart
Vice-Chairman—Lloyd Ebert, Oliver Corp., Michigan City
Secretary—W. G. Fassnacht, Bendix Products Div., Bendix Aviation Corp., South Bend
Treasurer—J. A. Miller, Bendix Aviation Corp., South Bend
Executive Committee—James Beaton, Joseph Strauss, H. E. Kellogg.

Following the business meeting, an entertaining film on Glacier National Park and Canadian fishing was shown. The balance of the evening was highlighted by the distribution of door prizes by means of a lively Bingo game. Winners were free to "gorge" themselves on hot dogs and beer if desired.

Brazing

Springfield, Ill.—F. Emery Garriott, [illegible], Ampco Metal, Inc., Milwaukee, Wis., excellently covered the subject "Jobs You Can Do With Bronze Electrodes and Filler Rods" at the May 11th meeting of the *Sangamon Valley* Section.

Election of Officers

Youngstown, Ohio.—The *Mahoning Valley* Section announces the election of the following officers for 1954–55:

Chairman—W. D. Colber, Jr., Chicago Bridge & Iron Co., Greenville, Pa.
1st Vice-Chairman—George C. Fogg, National Cylinder Gas Co., Youngstown, Ohio
Secretary-Treasurer—N. G. U'Halie Mercer Tube & Manufacturing Co., Sharon, Pa.

Plant Visit

Youngstown, Ohio.—The final meeting of the Season of the *Mahoning Valley* Section was held on May 11th. This meeting was devoted to a joint plant visit with the ASM of the United Engineering and Foundry Co. in New Castle, Pa.

LIST OF NEW MEMBERS

Effective April 30, 1954

MEMBERSHIP CLASSIFICATION

A—Sustaining Member
B—Member
C—Associate Member
D—Student Member
E—Honorary Member
F—Life Member

ATLANTA

Simon, Ralph W. (B)

BIRMINGHAM

Beals, C. L. (B)
Burell, John H. (C)
Cummings, J. B. (C)
Keenum, Albert Howard (C)
Patrick, James R. (B)
Pittman, James L. (B)

BOSTON

Jerome, E. Raymond, Jr. (B)
Keene, Harold W. (C)
Kirk, William D. (C)

CANADA

Gaudreault, Laureat (B)

CHATTANOOGA

Kaylor, Elmer Cary (D)
Lee, Paul B. (B)

CHICAGO

Boersma, Ed (C)
Brown, Alfred C. (C)
Kron, Lewis S. (C)
Loynd, Richard B. (B)
Mansbridge, Charles A. (B)
Marsh, Milton M. (C)
Peterson, Le Roy F. (B)

CINCINNATI

Archer, Robert H. (B)
Barnhouse, Richard A. (B)
Berg, John A. (B)
Hacker, Donald E. (C)

CLEVELAND

Burdett, John A. (C)
Chamberlain, P. C. (C)
Egli, Donald A. (B)
Heestand, Willard E. (B)

DALLAS

Drumgold, Joe F. (B)
Laughlin, J. E. (C)
Tankersley, T. B. (C)

DAYTON

Gilbert, Eugene V. (C)
Herzog, Paul D. (C)

DETROIT

Childs, John J. (C)
Farrell, Merton G. (C)
Hoenes, William (B)
King, Leo A. (B)
Knisely, Wade L. (C)
La Rose, J. H. (C)
McGraw, Robert E. (B)
Wagner, Charles F. (B)
Wolgast, Raymond P. (C)

HARTFORD

Knight, Cecil (C)
Skarupa, Michael J. (C)

HOUSTON

Brown, N. L. (C)
Cooke, E. F., Jr. (B)
Crooke, J. O. (B)
Dorrell, Will R. (B)
Frazier, Mack (C)
Hays, James A. (B)
Herben, Chris H. (C)
Jewell, W. J. (B)
Kohanek, Jesse Roy (D)
Kovalcik, John A. (D)
McGinn, Richard J. (B)
Miller, P. E. (C)
Owens, Luther (C)
Peyton, James L. (C)
Rollen, Leo Frank (B)
Ross, Earl A. (D)
Seale, Albert B. (C)
Sibley, Bradford J. (B)
Sterling, Harry L. (C)
Tharp, D. A. (B)
Tolle, Robert Garnett (B)
Vickers, Henry K. (D)
Watkins, Charlie Edward (B)
Weis, John L. (B)

INDIANA

Driver, Bernard L. (C)

IOWA

Brown, Hiram (B)

KANSAS CITY

Wyckoff, E. R. (B)

LEHIGH VALLEY

Spanik, John (C)
Strunk, Albert (B)

LOS ANGELES

Creso, Robert L. (C)
Harman, Glen P. (B)
Razo, Mariano (C)
Rohrberg, Roderick G. (D)
Sherman, Herbert John (C)

MAHONING VALLEY

Ashton, W. E. (C)
Day, Paul (C)
Hutchison, Roscoe Azale (C)
Little, James C. (C)
Olenik, Leonard E. (C)
Sands, Morton H. (C)
Santucci, Augustine J. (B)
Yarov, Ralph R. (C)

MARYLAND

Lebar, Stanley (C)
Wood, Walter Bruce, Jr. (B)

MILWAUKEE

Cieszynski, John (C)
Dient, Robert S. (C)
Fike, John P. (C)
Johnson, Arthur (B)
Kovensky, Albert (C)
Stattler, George J. (C)

NEW JERSEY

Anderson, Knute (B)
Clarke, John (B)
Di Nardo, A. (B)
Grillo, George J. (C)
Herold, William (C)
Kelly, William (B)
Krusch, William (C)
Lee, Henry R. (B)
Marion, Wallace C. (B)
Mitchell, Thomas (C)
Pease, George R. (B)
Roth, Jerome M. (B)
Skinner, Herbert J. (C)
Stavenick, Leo V. (B)

NEW ORLEANS

Brown, George J. (B)

NEW YORK

Alvar, John (C)
Angiulo, Anton (B)
Bell, J. K. (B)
Berry, Keith W. (C)
Boyle, Joseph A. (B)
Brosnan, Francis C. (C)
Carlin, Harry F. (B)
Carson, Joseph M. (B)

Coderre, A. J. (B)
Downs, F. S. (C)
Drucker, Jules H. (B)
Erdman, I. (B)
Galitsis, George P. (C)
Giambra, Frank (B)
Gresalfi, Paul (C)
Hanbrich, Charles C. (B)
Harman, Edward (C)
Heller, William (C)
Howe, George N. (C)
Jaworski, Edward (B)
Kent, Richard Thayer (B)
Keoning, Ewald (B)
Kirchner, Kenneth (B)
Klein, Frank (C)
Kollock, Alan S. (B)
Kosnoski, Stonnie (B)
Luciani, Nicholas (B)
Macaluso, Salvatore (C)
Malis, Frank J. (B)
Mathon, Albert (B)
Meringer, George W. (B)
Netz, George F. (B)
Nielsen, Edgar W. (B)
Noble, Edward (C)
Novak, Frank (B)
Peorini, Aldo (B)
Porritt, William A. (C)
Quinn, George (B)
Robertson, John S., Jr. (B)
Romann, Eric F. (C)
Romano, Frank (C)
Schaal, Harry J. (C)
Shokey, Thomas (B)
Stein, Edward J. (B)
Symington, Allwyn E. (B)
Titone, Charles (B)
Van Hensbroek, A. W. B. (C)
Vincenz, Thomas (C)
Wilmot, Raymond (C)
Wohlers, Frederick A. (B)
Wolf, Edwin F. (B)

NIAGARA FRONTIER

Arber, William A. (C)
Hughson, George (B)
Schauer, Arthur H. (C)
Wilson, Chas. F. (B)
Woodin, J. (D)

NORTHEAST TENNESSEE

Massengill, J. A. (B)
White, S. R. (B)

NORTHERN NEW YORK

Grotke, Gordon (C)

NORTHWEST

Wilson, Dave H. (C)

OKLAHOMA CITY

Ballew, Monte S. (D)
Bledsoe, Claud D. (D)
Brooks, Bob J. (D)
Cobb, Joel C. (D)
Cockrell, Glenn O. (B)
Davis, Marion H. (D)
Easlon, Odell Leon (D)
Fleener, Buddy (D)
Garrett, Evert W. (D)
Gibson, Russell C. (D)
Hill, Billy Jim (D)
Irwin, James F. (D)
Kinser, Arthur D. (B)
Packer, William D. (D)
Ramseyer, Jerry L. (D)
Rorick, Charles Edwin (B)
Schmoldt, Robert E. (D)
Smethers, Jess J. (D)
Stauffer, David F. (D)
Stilwell, Calvin John (D)
Stout, Robert R. (D)
Thompson, Robert (D)
Trent, David (D)
Wilkerson, Frank (D)
Wilson, Robert E. (D)
Woodin, J. (D)

PHILADELPHIA

Collier, Gordon T. (C)
Hans, Peter J. (B)
Hasselberg, Robert W. (B)
McWilliams, F. X. (B)
Stanley, Edward M. (C)

PITTSBURGH

Doerrer, C. L. (B)
Freeman, Dean (B)

PORTLAND

Kierulff, John L. (B)

RICHMOND

Duffey, Frank D. (C)
Gordon, Stover W. (C)
Laurence, L. M. (C)

SAGINAW VALLEY

Gamache, Clifford H., Sr. (B)
Keeler, Ralph (B)

SALT LAKE CITY

Hall, Ellis Y. (C)
Hekking, John P. (C)
Logan, Jac (B)

SANGAMON VALLEY

Purcell, Wilbur (C)

ST. LOUIS

Clemens, James A. (C)
Ritchie, David Fraser (C)

SUSQUEHANNA VALLEY

Farrell, Joseph H. (C)
Lavinskas, Albert (C)
Reese, David E. (B)
Swepston, Harry D., Jr. (C)

TOLEDO

Dunn, John L. (C)

TUCSON

Duane, Anderson (B)

TULSA

Dorrell, I. Fred (B)
Lukken, Robert M. (B)
Payne, Charles Eugene (C)

WASHINGTON

Hill, Willard J. (C)

WICHITA

Steele, Charles A. (B)
Wadsack, R. J. (B)

WORCESTER

McDonald, E. F. (B)
Nigro, Michael F. (B)

YORK-CENTRAL PENNSYLVANIA

Taylor, Tom L. (C)
Tinnon, W. M. (B)

NOT IN SECTIONS

Bates, C. C. (C)
Black, John E. (B)
Bost, Terry V. (B)
Danes, L. E. (B)
Hill, Clair A. (B)
Hunt, Denzil (B)
Nirza, Mohd. Nasir (B)
Peterson, Jack L. (B)
Pettit, J. K., Jr. (C)
Sneed, Roscoe T. (B)
Sohr, Edvin (C)
Sonneland, Ralph E. (B)
Thompson, Norman (B)

Members Reclassified

During the month of May

FOX VALLEY

Miller, Niels C. (B to A)

LOS ANGELES

Epperheimer, Howard (C to A)

MAHONING VALLEY

Sands, Morton H. (C to B)
Yarov, Ralph R. (C to B)

NORTH CENTRAL OHIO

Slob, Walter (C to B)

SAN FRANCISCO

Kech, L. A. (C to B)

SOCIETY (Foreign)

Suzuki, Haruyoshi (D to C)

TUCSON

Currie, William C. (C to B)

abstracts of CURRENT WELDING PATENTS

prepared by V. L. Oldham

Printed copies of patents may be obtained for 25c from the Commissioner of Patents, Washington 25, D. C.

2,677,034—Flash Welder Control Means—Kingsley A. Doutt, Cortland, Ohio, assignor to Federal Machine & Welder Co., Warren, Ohio.

Doutt's patent relates to hydraulic control apparatus for a flash welder that has one fixed platen and a movable platen operated by a fluid pressure motor. The apparatus controls movement of the movable platen during the welding cycle and includes a secondary motor for controlling a valve that controls the flow of hydraulic fluid to the fluid pressure motor. Other means connect the secondary motor to the valve to change the valve setting during the welding cycle so that movement of the platen will follow a predetermined position-speed relationship during the flashing period of the welding cycle.

2,677,035—Double-Arm Spot Welder—George D. Brent, Bloomfield, N. J., and Herbert S. Fox, Plover, Wis., assignors to Westinghouse Electric Corp., E. Pittsburgh, Pa., a corporation of Pennsylvania.

This patent relates to a double-arm spot welder for mounting a lamp filament assembly. The apparatus includes a reflector assembly having a reflector and a pair of lead-in conductors, while a frame is provided and has an anvil adjustably mounted thereon. An adjustable light center locating plate is carried on the frame adjacent the anvil for positioning the reflector assembly with respect to a filament on the anvil. Other welding electrode and circuit means are provided in the apparatus so that one filament support can be welded to one conductor and another filament support can be welded to the other conductor.

2,677,036—Arc-Welding Process and

APPARATUS—Amel R. Meyer, Griffith, Ind., and Clarence Verbeck, Lansing, Ill., assignors to Graver Tank & Mfg. Co., Inc., East Chicago, Ind., a corporation of Delaware.

The process disclosed in this patent is for use on a workpiece having a surface in other than the flat downhand position. The process includes the steps of traversing a welding area with a flux-submerged arc and compressing a portion of the melt formed by the arc to displace molten flux therefrom while keeping the molten metal substantially undisturbed. The displaced molten flux is removed from the welding area.

2,677,037—WELDING APPARATUS AND METHOD—William N. Platte, McKeesport, Pa., assignor to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

This patent teaches a method of flash welding comprising applying a voltage between members, moving the members relative to each other to effect burnoff, and maintaining a predetermined variable relation between the voltage and the rate of movement of the members. The process maintains a minimum voltage for satisfactory flashing between the members.

2,677,744—PORTABLE ELECTRICAL SPOT WELDER—Wolfgang B. Fahrenbach, Oakland, Calif.

This electrical welding tool comprises a transformer having a hole therethrough, and means providing fixed and movable welding tips positioned adjacent the transformer at one end of the hole. A motor is provided at the other end of and outside of the hole and means extend freely through the hole and are spaced from the transformer surfaces. Such means extend to the movable welding tip and to the motor so that the tip can be driven by the motor.

2,677,745—ELECTRODE HOLDER—Edgar D. Leon, Detroit, Mich.

This patented electrode holder includes a hollow nonconductive housing closed at one end and a pair of elongated conductive interfitted relatively movable grips within the housing. Spring means are positioned intermediate the grips to effect longitudinal movement of the grips with relation to each other and an electrode receiving hole is provided in the electrode assembly.

2,677,746—MACHINE FOR BUTT-WELDING OR END-SHAPING CABLES OR THE LIKE AND ITS METHOD OF UTILIZATION—Gabriel Victor Alphonse Duch and Marie Adrienne Duch, nee Barnelin, Lyons, France.

In this patent, a pair of jaws including a base element and a cover element are hingedly connected and locking means are provided for holding the cover element in closed position. Matching semicylindrical recesses are provided in the two elements and interchangeable half bushings are removably engaged with the recesses. A centering stud is carried by the bushing in the base element and it engages a hole in the base element proper for centering the bushing therein.

2,678,367—ELECTRIC RESISTANCE WELDING MACHINE FOR SPOT OR SEAM WELDING—Kuno Eisenburger, Wels, Austria, assignor to M & S Maschinen und Stahl A.G. Zollikon-Zurich, Switzerland.

Eisenburger's patent is on an electric resistance welding machine wherein the casing of a supply transformer forms an essential portion of the secondary of the transformer. The holding means of at least one of the electrodes comprises one resilient part and the holding means of both electrodes are otherwise rigid. An elastic partition is inserted in the casing and an arm connects thereto and to one of the electrodes. A bag is arranged in the space between a portion of the casing and the partition and a pressure medium can be supplied to the bag.

2,678,368—APPARATUS FOR HIGH-FREQUENCY INDUCTION SEAM WELDING—James W. Williamson, Cleveland, Ohio, assignor to the Ohio Crankshaft Co., Cleveland, Ohio, a corporation of Ohio.

Williamson's patent is on a continuous seam-welding apparatus for a tube with longitudinally split edges that is continually advanced along a predetermined path with its edges in spaced relationship. These edges are brought into abutting and electrical engagement at a predetermined point and the high-frequency inductor surrounds the tube in advance of the point. The patent particularly relates to the provision of a narrow elongate member of magnetically permeable material that is disposed between the exit end of the inducing means and the point of engagement of the edges of the tube blank with such member being placed in close-spaced parallel relationship with such edges.

2,678,369—ARC WELDING EYESHIELD CONTROL—William R. VanHook, Maxwell, Iowa.

This patent is considered to relate to a device for electrically connecting an auxiliary electrical machine to a main electrical machine when the auxiliary electrical machine, such as an eye shield, is worn by the operator of the machine, and a portion of the main machine, such as an electrode handle, is consistently grasped by the operator during operation of the main machine. The patent relates to certain electrical connections on a protective glove worn by the welder and contact plates provided on an electrode holder so that an electrical circuit can be closed when the operator grasps the electrode holder and the eye shield can be positioned operatively or inoperatively dependent upon whether the operator is then grasping the electrode holder or not.

2,678,370—METHOD AND MEANS FOR BUTT WELDING LARGE METALLIC SURFACES—Francis S. Denneen, Cleveland, Ohio, assignor to the Ohio Crankshaft Co., Cleveland, Ohio, a corporation of Ohio.

This patent relates to a method of heating large area surfaces preparatory to butt welding a pair of members together. High-frequency electrical currents are induced to flow in the members adjacent such large area surfaces and in a plane generally parallel to the surfaces with the currents being concentrated in the periphery of the surfaces because of the high-frequency current flow so that the exterior portions of the members in the vicinity of the surfaces are heated. A decreasing electrical resistivity is provided toward the center of the surfaces and low-frequency electric currents are flowed between the surfaces to be welded to provide a secondary heating primarily of the center of the surfaces.

2,678,987—APPARATUS FOR WELDING ON UPRIGHT SURFACES—Hyrum M. Talley, Alhambra, Calif., assignor, by mesne assignments, to Chicago Bridge & Iron Co.

This patented apparatus is adapted for welding on upright surfaces and includes a carriage and means for mounting the carriage adjacent upright work to be welded and having horizontal movement with relation thereto. Other means are provided to feed an electrode toward the work as the carriage progresses toward the work and rollers are mounted on the carriage on opposed sides for rotation about vertical axes. An endless rubber belt is trained over the rollers and has a reach therebetween engageable with the work beneath the electrode feeding means to support flux against the work. Other means feed flux onto the belt adjacent the electrode feed means and the belt functions to crowd flux against the work.

CLEANING BEFORE SPOT WELDING ALUMINUM

Improve quality of welds! Increase number of spot welds before tip cleaning! Prolong life of electrode tips! Eliminate tedious, expensive mechanical cleaning!

DIVERSEY Pre-Welding Treatment for Aluminum

DIVERSEY no. 36 CLEANER

DIVERSEY no. 514 DEOXIDIZER

If you are looking for improved spot welds, increased production and lower costs, it will pay you to investigate the famous Diversey Pre-Welding Treatment for aluminum now . . . it's practical, proved superior, easy and surprisingly economical to use!

Diversey Pre-Welded Treatment is possible because of two outstanding Diversey developments . . . No. 36 cleaner for removing identification markings, grease and soil; No. 514 deoxidizer for removing oxide and heat scale!

A Diversey D-Man will be happy to show you the advantages of Diversey Pre-Welding Treatment for aluminum! No obligation! Write today! Complete information is available!

PROTECTING QUALITY · ASSURING PURITY · DIVERSEY CHEMICALS AND SERVICES

THE DIVERSEY CORPORATION

Metal Industries Department

1820 Roscoe Street · Chicago 13, Illinois

In Canada: The Diversey Corporation Canada Ltd., Lakeshore Rd., Port Credit, Ont.

INDEX TO ADVERTISERS

Air Reduction ..... Outside back cover
Alloy Rods 714, 715
American Chain and Cable 721
American Manganese Steel Div. 712, 713
Anaconda 699
Arcos Corporation 710, 711
Aronson Machine Co. 700

Becker Brothers Carbon Co. 702

Crucible Steel Co. 717

The Diversey Corporation 732
Drawalloy Corporation 707

Fansteel Metallurgical Corporation
W. W. Alloys, Inc., Division 726

General Electric 689, 708, 709

Hobart Brothers Company 627

International Nickel Co. 632

Jackson Products ..... Inside back cover

The Lincoln Electric Company 687
Linde Air Products Company, a Division of
Union Carbide and Carbon Corp. 630

P. R. Mallory & Co., Inc. 629
Metal & Thermit Corporation 628
Miller Electric Manufacturing Co. 697

National Carbide Company 701
National Welding Equipment Co. 703

Page Steel and Wire Division 721

Smith Welding Equipment Corp. 705
Square D Company 723
Stahl Equipment Company 704
Stulz-Sickles Co. 716

Tube Turns, Inc. 691, 692
Tweco Products Company ..... Inside front cover

Union Carbide and Carbon Corporation
Linde Air Products Company 630
United States Testing Company, Inc. 704

W. W. Alloys, Inc.
Division of Fansteel Metallurgical Corp. 726
Westinghouse Electric Corporation 702

WELDING RESEARCH COUNCIL
of the Engineering Foundation

Sponsored by the American Welding Society, American Institute of Electrical Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Civil Engineers, American Society of Mechanical Engineers, Society of Naval Architect and Marine Engineers, American Society for Metals and American Society for Testing Materials

Supplement to the Welding Journal, July 1954

Effect of Electrode Type in the Notch Slow-Bend Test

Using the Kinzel Test, no increase in notch toughness is obtained with overmatching electrodes in welding plain carbon and high tensile steels as compared with E6010 electrodes

by William J. Murphy and R. D. Stout

Synopsis

The Kinzel longitudinal bead slow-bend test has been used to evaluate the effect of overmatching and low-hydrogen electrodes upon the notch toughness of a plain carbon Grade A-212 steel and low-alloy high-tensile-strength steels.

Comparison of transition temperatures at 1% lateral contraction for the steels welded with E6010, E7015, E10015, E12015 and E310 (25/20 Cr/Ni) shows no significant effect of the use of overmatching electrodes except that tests with the E310 stainless electrode show marked improvement in notch toughness.

Whether the Kinzel Test was prepared with single bead on plate, multiple bead on plate or full double-V butt-welded specimens, no increase in notch toughness was obtained with E12015 overmatching electrodes as compared to E6010 electrodes.

INTRODUCTION

EXPERIMENTS employing explosion bulge testing techniques have demonstrated that an apparent advantage in notch toughness results when overmatching low-hydrogen electrodes are used for full scale weldments.[1] In these tests it was shown that the nature of the weld metal controlled the performance of the weldments and it was postulated that the effect was due (1) to a premium of notch toughness of the high strength weld metal as compared to the low strength weld metal and (2) to strain deconcentration in the weld zone as a result of overmatching strength in the weld.

The experimental work described in this paper was undertaken to determine if notch slow-bend tests would produce results comparable to explosion bulge tests; i.e., whether the effects postulated above operate in the notch slow-bend test. The test selected for these experiments was the standard Kinzel test.

TEST MATERIALS

Two grades of steel were selected for experimental investigation: (1) low-alloy high-tensile Navy HTS steel and (2) silicon-killed plain carbon steel, ASTM Spec. A-212 Grade B. Two heats of the HTS steel were used. Compositions of the steels are listed in Table 1.

Table 1—Steel Compositions

Steel	*Heat*	*C*	*M_2*	*P*	*S*	*Si*	*Ti*
HTS	L	0.13	1.24	0.016	0.019	0.27	0.009
HTS	M	0.14	1.29	0.029	0.040	0.18	0.015
A-212	K	0.25	0.66	0.020	0.022	0.19	...

The steels were supplied as 1-in. plate and the HTS

William J. Murphy is Instructor and **R. D. Stout** is Professor of Metallurgy at Lehigh University, Bethlehem, Pa.

Presented at the AWS National Spring Meeting held in Buffalo, N. Y., May 4–7, 1954.

steels were normalized at 1600° F prior to welding.

The electrodes used are listed in Table 2.

Table 2—Electrode Classes Tested (All 5/16 In. Diam)

E6010	Mild steel
E7015	Mild steel
E10015	Manganese-molybdenum
E12015	Manganese-molybdenum-vanadium
E310	25/20 Stainless

The EXX15 and the E310 electrodes were supplied in 40-lb hermetically sealed containers. Once opened, these containers were stored in an oven at 300° F and electrodes were removed from the oven one at a time for welding.

EXPERIMENTAL PROCEDURE

Single Bead-on-Plate Specimens

Initial tests were conducted using the Kinzel specimen with a single bead-on-plate weld. Specimens 1 x 3 x 12 in. were cut from the plate with the rolling direction parallel to the longitudinal axis of the specimen. The specimens were welded with an automatic head, using a single longitudinal bead 8 in. in length on the plate, after which they received a standard Kinzel notch 4 in. from each end. The welding conditions were as follows: 185 amp and 28 arc volts for the E6010 electrodes and 200 amp and 22 arc volts for all other electrodes. Travel speed was uniformly 6 ipm.

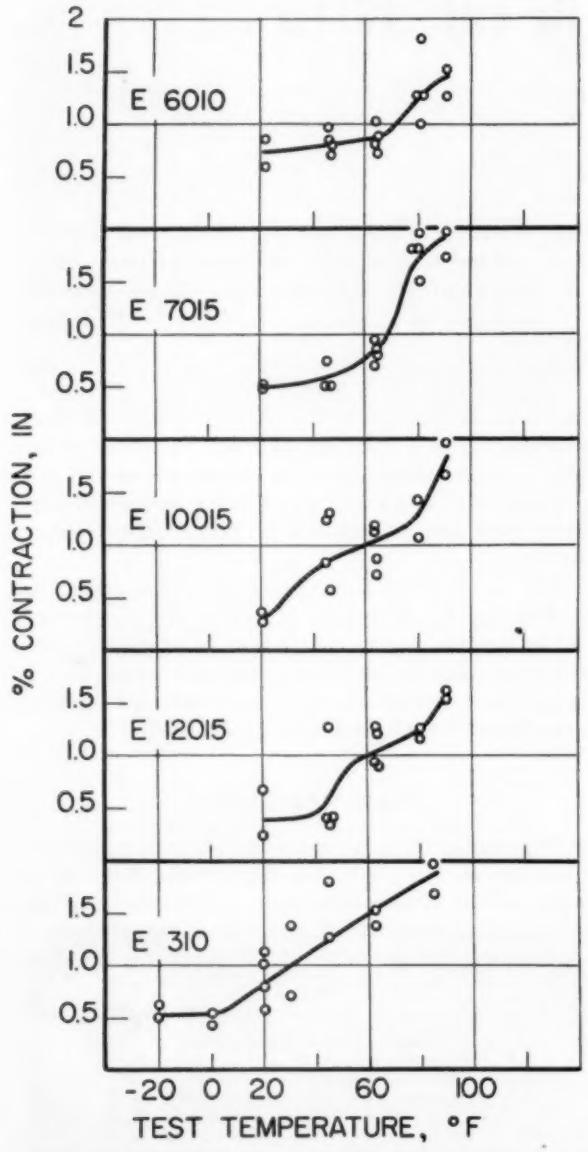


Fig. 1 Effect of electrode type on notch toughness of steel "K," single bead on plate Kinzel specimens

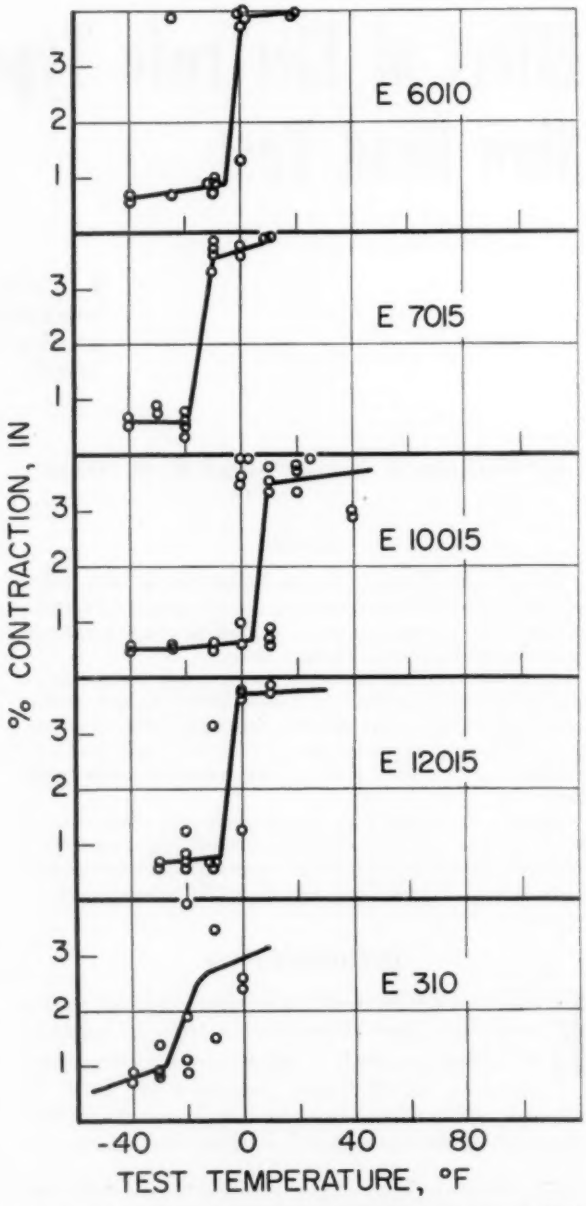


Fig. 2 Effect of electrode type on notch toughness of HTS steel "L," single bead on plate Kinzel specimen

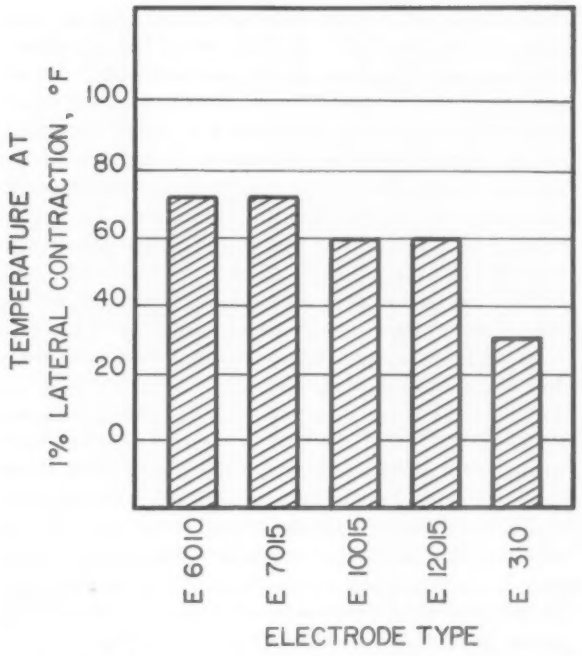


Fig. 3 Effect of electrode type on notch toughness of steel "K," single bead on plate Kinzel specimen

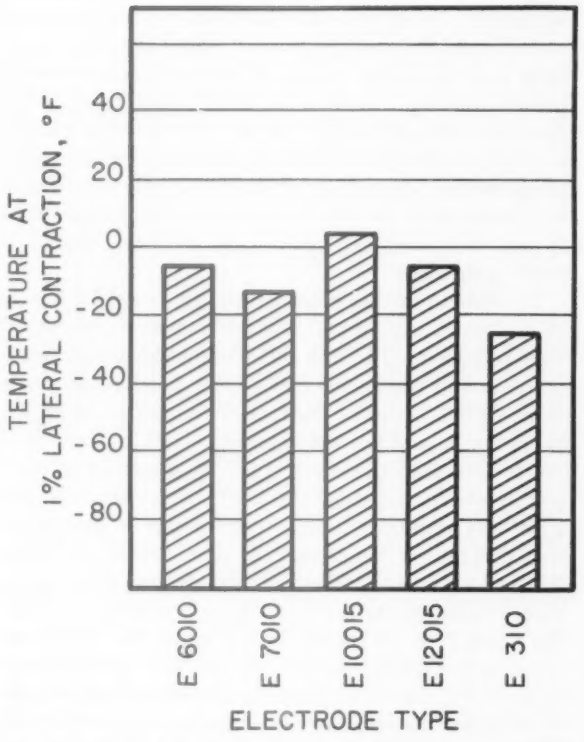


Fig. 4 Effect of electrode type on notch toughness of HTS steel "L," single bead on plate Kinzel specimen

Results of slow bend tests for specimens welded with each of the five electrodes are plotted in Figs. 1 and 2.

On the basis of 1% lateral contraction, the transition temperatures for these electrodes are compared in Figs. 3 and 4. It is apparent from these data that with but one exception the effect of the electrode upon notch toughness of the two steels in the Kinzel test is negligible. Use of the stainless electrode, however, results in a definite improvement in notch toughness.

Since the penetration of the 25Cr – 20Ni stainless electrode was somewhat less than that of the other electrodes, additional tests were conducted to determine if this factor was responsible for the improved notch

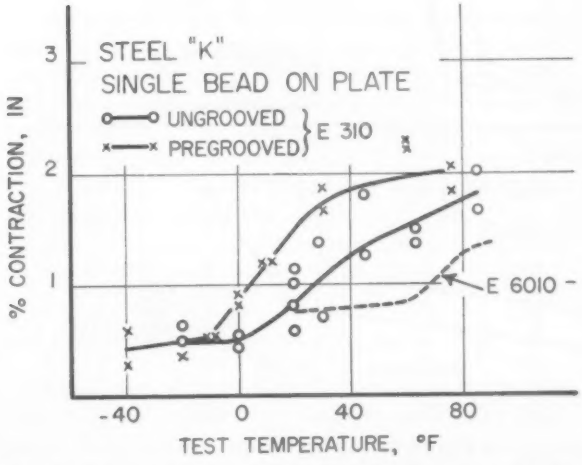


Fig. 5 Influence of increasing amount of stainless weld metal beneath notch root obtained by pregrooving

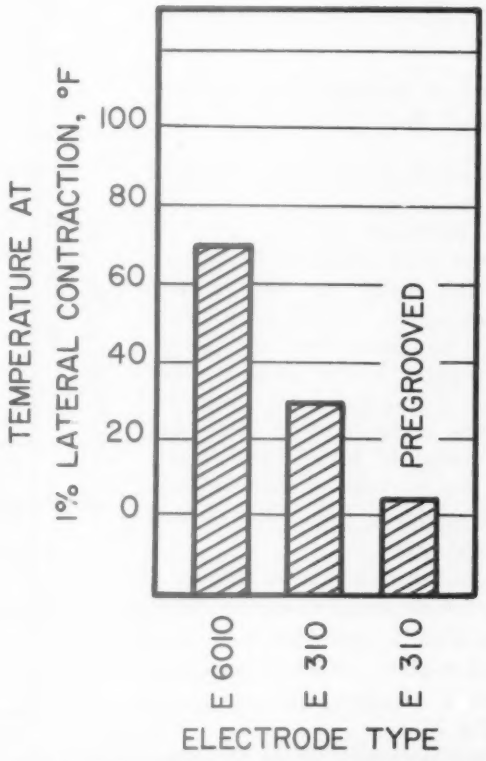


Fig. 6 Influence of increasing amount of stainless weld metal beneath notch root obtained by pregrooving

toughness. An increase in weld metal beneath the notch was effected by machining longitudinal grooves 1/16 in. deep and 1/4-in. root radius in the bend test specimens before welding. Results of bend tests using these specimens are compared with the ungrooved specimens in Fig. 5. Bar graphs showing comparative transition temperatures under these conditions are shown in Fig. 6. It appears from these data that increasing the quantity of austenitic weld metal below the notch root improved notch toughness.

In order to further demonstrate the beneficial effects of austenitic weld metal two new series of specimens were prepared. The first series was welded with bead-on-plate and transverse Charpy-vee notches were machined 0.095 in. deep, the root of the notch being just below the root of the weld nugget. Thus, in these slow notch-bend tests the effect of the weld metal was completely eliminated while the effect of the heat-affected zone was retained. The second series of specimens was pregrooved longitudinally to a depth of 1/8 in. With Charpy-vee notches 0.095 in. deep in these specimens, considerable weld metal was present beneath the notch root. With the fact in mind that these two series of test specimens were not standard Kinzel specimens, the bend tests showed a transition temperature of 80° F for the pregrooved specimens with weld metal under the notch as against 105° F for the specimens with no weld metal under the notch. The presence of austenitic weld metal under the notch again was beneficial.

Tests on Multiple Bead and Full-Scale Butt-Welded Specimens

It was shown above that, in general, the use of low-hydrogen overmatching electrodes did not give improved notch toughness as measured by the Kinzel test with a single bead-on-plate. Since explosion bulge tests do demonstrate such an improvement, further attempts were made to approach more closely conditions encountered in these tests by means of Kinzel tests employing multiple bead-on-plate specimens and specimens from full-scale butt-welded joints.

The notch toughness of Steel M was first determined using both E6010 and E12015 electrodes with single bead-on-plate Kinzel specimens. Results of these tests are plotted in Fig. 7.

Multiple-bead Kinzel specimens were prepared in order to determine if increasing the quantity of weld metal at the notch root would accent the effect of weld metal in the bend test and thus reveal definite differences in notch toughness due to electrode type. Bend-test specimens of Steel M were prepared with a longitudinal groove 1/16 in. ep and 1 in. wide. Welding was accomplished by laying three longitudinal beads at 10 ipm side by side (center bead last) at the bottom of the groove and a final bead at 6 ipm over the center bead. As a result the root of the notch intersected weld metal over a length of about 1 in. E6010 and E12015 electrodes were used. Results of slow notch-bend tests on these specimens are plotted in Fig. 7.

In addition Kinzel tests prepared from full-scale double-vee butt-welded specimens were included to duplicate the welds in explosion bulge test specimens. Plates of Steel M, 1 x 6 x 24 in., were double-vee butt welded with E6010 and with E12015 electrodes along the 24-in. side. Five to six passes per side were required and the maximum interpass temperature was 120° F. After welding the weldments were radiographed. Kinzel test specimens with the double-vee weld on the longitudinal axis were then machined from the butt-welded plates and tested. Results are plotted in Fig. 7.

Examination of Fig. 7 reveals that in no case was the E12015 overmatching electrode superior to the E6010 electrode. In fact, the reverse case was found to be

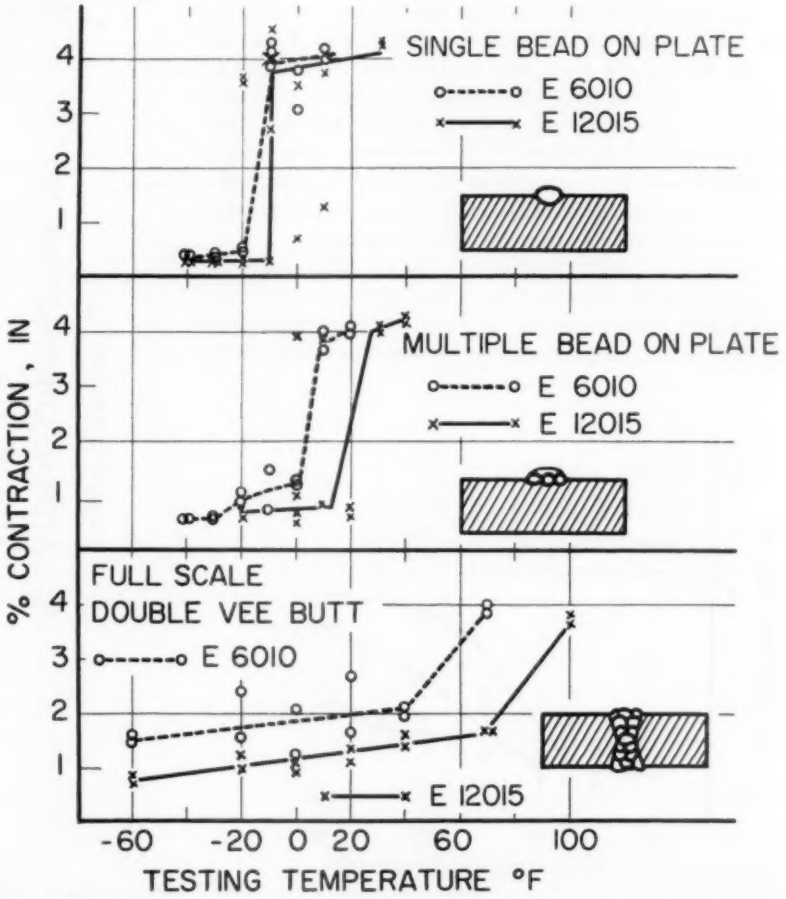


Fig. 7 Effect of electrode type on notch toughness of HTS steel "M," showing effect of increasing amounts of weld metal at notch root

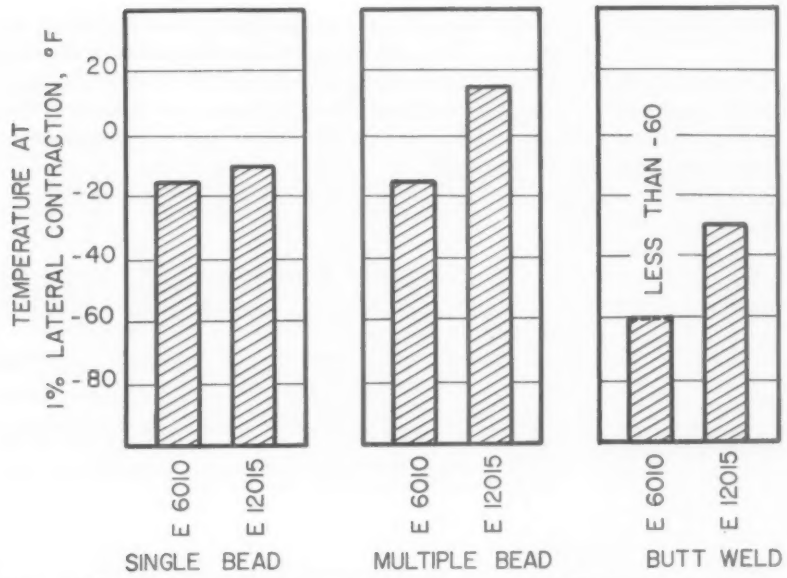


Fig. 8 Effect of electrode type on notch toughness of HTS steel "M," showing effect of increasing amounts of weld metal at notch root

true for multiple-bead and double-vee butt-welded specimens. These results are shown more clearly in the bar graphs of Fig. 8. In the tests on full-scale welds the overmatching E12015 electrode performed more poorly than in bead-on-plate tests.

DISCUSSION OF RESULTS

Test results reported here indicate that in general the nature of the deposited weld metal has little effect upon notch toughness as measured by the slow notch-bend test. This is in contrast to results of explosion bulge tests where it was shown that high-strength weld metal with a premium of notch toughness resulted in improved performance of weldments. Differences in the performance of welded steel as measured by these two tests may be explained by the fact that the test conditions and the test specimens themselves are quite different. In the slow notch-bend test there are relatively slow strain rates and a condition of imposed stress concentration at the site of the notch, while in the explosion bulge test there are rapid strain rates and freedom to yield in obedience to the relative yield strengths of the various regions of the weldment.

It is evident that notch toughness tests may respond differently to some of the variables of welding and at present for certain welding problems it is not possible to decide which test will afford the best information.

GENERAL COMMENTS

One cannot help but sympathize with the reader who tries to fit the results from the various types of specimens into a consistent picture in which the influence of welding on notch toughness is in proper focus. For example the notch-bend test in somewhat varying dimensions is used by one group of investigators to show the embrittling effect of weld microcracks,[2] by another to show the contribution of coarsened and hardened heated zones[3] and by a third to demonstrate the overweighing influence of the unaffected base plate.[4] The explosion test specimen, with or without weld reinforcements intact,[1, 5] may be used to contrast the behavior of various electrode types or, with weld reinforcement removed, may be shown to be controlled by arc strikes regardless of the principal weld metal present. One is led to conclude either that the effects of welding are quite complex or that laboratory testing has brought a number of extraneous factors into consideration.

Some of the difficulty springs from the dubious goal of finding a single test specimen to reproduce the behavior of all welded structures. At present no such specimen can be recommended, and even if its general shape and means of fabrication were established there would still be the knotty problems of how it should be notched, how it should be loaded, how its behavior should be measured and how the measurements should be interpreted and correlated to engineering structures. Certainly one cannot reach a decision about welded specimens while there is so little agreement in the interpretation of notch toughness tests for unwelded steel.

From the mass of data that has been assembled on the notch toughness of welded steel there are certain facts that are so well substantiated by testing methods of all types that there need be no hesitation in translating them to service performance. Thus, the composition of the steel, particularly carbon content and probably Ni, Mn and P content, is known to be influential, also deoxidation practice and prior heat treatment. The action of welding on the geometry of steel structures is well appreciated, e.g., the notches introduced by weld ripples, undercutting, incomplete penetration, etc. It is not so apparent, however, how all of these factors coupled with other nonwelding variables can be evaluated in an actual structure, and so the analysis of welding effects has had to be statistical. The use of a multitude of test specimen designs produces a good deal of confusion, but it is perhaps the only way that a thorough understanding of such an involved subject can be reached.

SUMMARY OF RESULTS

1. The notch toughness of an HTS steel and an A-212 steel in the longitudinal bead notch-bend test with a single bead-on-plate was not affected by the

type of electrode with the exception of the 25Cr – 20Ni electrode.

2. Use of a stainless 25Cr – 20Ni, E310 electrode resulted in a definite improvement in notch toughness as compared to the other electrodes. This improvement was increased when the amount of austenitic weld metal beneath the notch root was increased.

3. With multiple longitudinal beads, E6010 electrodes produced better notch toughness in the Kinzel test than E12015 overmatching electrodes. This became even more marked with full-scale double-vee butt welds.

ACKNOWLEDGMENT

The project reported here has been carried out under the auspices of the Welding Research Council with funds supplied by the American Iron and Steel Institute. The authors appreciate the guidance provided by the Subcommittee including R. H. Aborn, Chairman, and Messrs. Boardman, Jackson and Somers. They are grateful also for the advice and encouragement of W. Spraragen.

References

1. Hartbower, C. E., and Pellini, W. S., "Investigation of Factors Which Determine the Performance of Weldments," THE WELDING JOURNAL, 30 (10), 499-s to 510-s (1951).
2. Flanagan, A. E., Bocarsky, S. I., and McGuire, G. B., "Effects of Low-Temperature Cooling Rate on the Ductility of Arc Welds in Mild Steels," *Ibid.*, 22 (9), Research Suppl , 459-s to 465-s (1950).
3. Stout, R. D., and McGeady, L. J., "Notch Sensitivity of Welded Steel Plate," *Ibid.*, 28 (1), Research Suppl., 1-s to 9-s (1949).
4. Rieppel, P. J., and Voldrich, C. B., "Fracture Initiation and Propagation in Welded Ship Steels," *Ibid.*, 31 (4), Research Suppl., 189-s to 197-s (1952).
5. Mikhalapov, G. S., "Direct Explosion Tests of Welded Joints," *Ibid.*, 29 (3), Research Suppl., 109-s to 122-s (1950).

BULLETIN SERIES

Requests for single copies should be sent to the AMERICAN WELDING SOCIETY, 29 W. 39th St., New York 18, N. Y.

Requests for bulk lots ten or more, should be sent to the WELDING RESEARCH COUNCIL, 29 W. 39th St., New York 18, N. Y.

No. 1 Steel Compositions and Specifications, by Charles M. Parker, March 1949. $0.50.
No. 2 The Nature of the Arc, by J. D. Cobine, April 1949. $0.50.
No. 3 Burn-Off Characteristics of Steel Welding Electrodes, by D. C. Martin, P. J. Rieppel and C. B. Voldrich, May 1949. $0.50.
No. 4 Testing Pressure Vessels by F. G. Tatnall; Effect of Welding on Pressure Vessel Steels, by A. F. Scotchbrook, L. Eriv, R. D. Stout and B. G. Johnston, February 1950. $0.50.
No. 5 How Plastic Deformation Influences Design and Forming of Metal Parts, by John R. Low, Jr.; Brittle Fracture in Mild Steel, by J. S. Hoggart, May 1950. $1.00.
No. 6 Stress Corrosion Cracking of Stainless Steels by Helmer Nathorst; Part I. Practice Experiences; Part II. An Investigation of the Suitability of the U-bend Specimen, October 1950. $1.00.
No. 7 Instrumentation for the Evaluation of the Stability of the Welding Arc, by L. P. Winsor, L. McDonald Schetky and Robert A. Wyant, November 1950. $1.00.
No. 8 Tests of Columns under Combined Thrust and Moment, by Lynn S. Beedle, Joseph A. Ready and Bruce G. Johnston, December 1950. $1.00.
No. 9 Copper in Stainless Steels, by Helmut Thielsch, August 1951. $1.00.
No. 10 Thermal Fatigue and Thermal Shock, by Helmut Thielsch, April 1952. $1.00.
No. 11 Investigations of Effect of Fabrication Operations Upon Pressure Vessel Steels, by S. S. Tör and Robert D. Stout, May 1952. $1.00.
No. 12 An Analytical Study of Aluminum Welding, by C. O. Smith, E. R. Funk and H. Udin, June 1952. $1.00.
No. 13 A New High-Yield Strength Alloy Steel for Welded Structures, by L. C. Bibber, J. M. Hodge, R. C. Altman and W. D. Doty, July 1952. $1.00.
No. 14 Welding Processes and Procedures Employed in Joining Stainless Steels, by Helmut Thielsch, September 1952. $2.00.
No. 15 Slag-Metal Interaction in Arc Welding, by Nils Christensen and John Chipman, January 1953. $1.00.
No. 16 Ship Structure Research, Part I. The Third Technical Report of the Ship Structure Committee; Part II, Research Under the Ship Structure Committee, by Capt. E. A. Wright, Finn Jonassen and H. G. Acker, Nov. 1953. $2.00.
No. 17 A Critical Survey of Brittle Failure in Carbon Steel Structure Other Than Ships, by M. E. Shank, Jan. 1954. $2.00.

Alloy Welds Deposited in "Unalloyed" Titanium Base Metal: Part I

An investigation to develop a method for improving the toughness and strength of weld joints in "unalloyed" titanium

by C. E. Hartbower and Daniel M. Daley, Jr.

Synopsis

Realization of strong, tough welds in titanium and titanium alloy structures requires base and filler metals of high quality and exacting control of the welding technique. Interstitial elements derived either from the base or filler metals or introduced through insufficient inert-gas protection in the welding operation results in notch-sensitive welds. Because so-called "unalloyed" titanium can be welded more readily than the alloys of titanium which are currently commercially available, considerable applications have been made of commercially pure titanium. However, in order to realize tough welds using such material, both the base metal and filler have to be low in interstitial elements. Unfortunately, unalloyed titanium has insufficient tensile strength for most applications.

A somewhat unique approach to the problem of evaluating the weldability of titanium alloys has been developed at the Watertown Arsenal Laboratory. The method consists of depositing commercial titanium alloys in "unalloyed" base metal. By this device, medium to low-alloy weld deposits are produced as a result of the dilution obtained by the addition of arc-melted "unalloyed" base metal to the alloyed weld puddle. Thus, by varying the joint design and/or energy input in welding "unalloyed" titanium, it is possible to produce various compositions in the weld joint through the addition of commercial alloys as filler materials. The chemical composition of the weld deposit is then determined and the performance of the various alloys evaluated by mechanical testing. The results of this investigation are considered to be of immediate use in fabricating structures of titanium where yield strengths (0.01% offset) of between 50,000 and 75,000 psi are required.

Because so-called "unalloyed" titanium may contain widely varying amounts of carbon, oxygen, hydrogen and nitrogen, an evaluation was made of the effect of the interstitial elements on the properties and structure of "unalloyed" and alloyed weld deposits. The notched-bar impact test, in particular, demonstrated a marked embrittlement in "unalloyed" all-alpha weld deposits as the result of excessive interstitial content, and in alloyed alpha-beta welds as a result of carbon in excess of 0.10%.

C. E. Hartbower is Chief and **Daniel M. Daley, Jr.**, is Welding Engineer, Welding Section, Process Metallurgy Branch, Watertown Arsenal Laboratory, Watertown, Mass.

Presented at the Thirty-Fourth National Fall Meeting, AWS, held in Cleveland, Ohio, week of Oct. 19–23, 1953. Part II will be published in the August JOURNAL.

INTRODUCTION

Statement of the Problem

ALTHOUGH it has been demonstrated in a number of different researches using experimental heats of titanium that there are several alloying elements which will produce moderately high strength and at the same time provide as-welded ductility, the commerical alloys currently available are all too highly alloyed to be ductile in the as-welded condition. Consequently, when a proportional limit of 50,000 psi is acceptable to the designer, fabricators are using so-called "unalloyed" titanium for welding applications. The Army Ordnance Corps, for example, has produced base plates for the 80-mm mortar and gun trails for anti-aircraft mounts, and the Air Force has built compressor frames for jet engines—all from "unalloyed" titanium. Unfortunately, so-called "unalloyed" titanium contains excessive amounts of embrittling interstitial elements. However, the embrittlement of weld and base metal has generally escaped undetected because it is not demonstrated by the tensile test, particularly when a weld joint is tested transverse to the direction of tensile loading. V-notch Charpy impact testing, on the other hand, dramatically exposes the highly notch-sensitive condition that exists in much of the commercial "unalloyed" titanium.

In the early investigations at Watertown Arsenal Laboratory low-alloy alpha-beta weld deposits were found to be relatively notch tough as compared with "unalloyed" all-alpha deposits. For example. "unalloyed" filler metals deposited in alloy base metals were found to be consistently tougher than "unalloyed" fillers deposited in commercially pure titanium. Chemical analysis of the weld in the case of "unalloyed" filler deposited in RC-130A (7% Mn) base metal revealed that a 2.5% Mn had been picked up by the weld metal. The resulting Charpy impact-energy was 25 ft-lb at room temperature as compared with 5 ft-lb in "unalloyed" all-alpha weld metal. Investigations at

Battelle Memorial Institute[1] of the effects of the principal beta-stabilizing elements on weld joint properties in titanium indicated that titanium alloyed with 1 to 3% of beta-stabilizing element (chromium, iron, manganese, molybdenum or vanadium) provided ultimate tensile strengths of 60,000 to 120,000 psi with good bend ductility and appreciable notch toughness in the as-welded condition. The ductility and toughness of the welds were found to decrease rapidly with increasing alloy content, however, becoming very low when the alloy content exceeded about 3%. It was later concluded that the properties of welds in the alpha-beta titanium alloys were governed primarily by the quantity of beta-stabilizing elements present in the alloys rather than by the identity of the particular element(s) used.[2] When alpha-stabilizing aluminum was used as an alloying element, 5% aluminum produced a tensile strength of 102,000 psi with excellent notch toughness in both base metal and weld deposit. However, when manganese was added in combination with the aluminum, a marked improvement in tensile strength was realized with little or no loss of toughness. (3% Mn – 4% Al produced a tensile strength of 135,000 psi.)

Since titanium containing small amounts of substitutional solid solution elements is not commercially available, it was conceived at Watertown Arsenal Laboratory that low-alloy weld deposits could be produced by depositing alpha-beta type commercial alloys as filler metal in "unalloyed" base metal. By this device, low-alloy weld deposits could be produced as a result of the dilution obtained from the addition of arc-melted "unalloyed" base metal to the alloyed weld puddle (Fig. 1). It was anticipated that alloy weld metal would be advantageous in structures fabricated from "unalloyed" base metal in that the resulting higher strength weld metal would reduce the possibility of local yielding at points of strain concentration in the weld, and would reduce the transweld component of strain in the weld and thereby increase the rigidity of the weldment as a whole when subjected to stress in excess of the proportional limit. Thus, the objective of this investigation was to develop a method for improving the toughness and strength of weld joints in "unalloyed" titanium. Because so-called "unalloyed" titanium was found to contain various contents of the interstitial elements carbon, oxygen, hydrogen and nitrogen, a secondary objective became mandatory; viz. evaluation of the effect of the interstitial elements on the properties and structure of "unalloyed" and alloyed weld deposits.

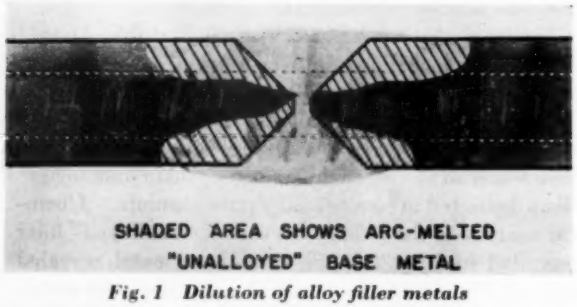


Fig. 1 Dilution of alloy filler metals

Macrophotograph (mag. 3 ×) illustrates the method used to obtain low-alloy alpha-beta weld deposits. In the weld shown, the filler originally contained 6.6% Mn; after deposition in "unalloyed" base metal, the weld metal contained only 1.6% Mn. In addition to the dilution effect some manganese was lost as a result of vaporization.

Literature on the Effect of Interstitial Elements

D. C. Martin of Battelle Memorial Institute[3] has reported an investigation of the effects of carbon, oxygen and nitrogen on welds in titanium. Inert-gas-shielded tungsten arc and spot welds were made in iodide titanium sheet, in sheet prepared from sponge, and in binary alloys prepared from sponge titanium containing deliberate additions of carbon, oxygen and nitrogen. The alloys included compositions in the range of 0.13 to 0.74% carbon, 0.15 to 0.55% oxygen and 0.13 to 0.24% nitrogen.

The tensile and bend properties of welds in iodide sheet and in sponge-base sheet without deliberate addition of interstitials were found to be about the same as the properties of the unwelded base materials. The results of tests on sponge-base carbon alloys indicated that with up to 0.13% carbon, such alloys have good weldability. However, at some composition level between 0.13 and 0.28%, carbon begins to have an adverse effect. At 0.55% carbon the bend ductility of the arc welds was practically zero. In the case of sponge-base alloys containing deliberate additions of oxygen, the authors observed that oxygen additions up to 0.15% had no bad effects on the properties of arc welds; the bend ductility of welded 0.15% oxygen sheet was found to be about the same as for unwelded sheet and not too much lower than that of welds in unalloyed sponge-base sheet. However, with oxygen contents of 0.30% and above a marked embrittlement was noted with numerous small cracks in the as-deposited weld metal.

In the case of the nitrogen alloys it was apparent from both the tensile properties and bend tests that 0.13% nitrogen was seriously embrittling. At this nitrogen level, cracks occurred in the weld deposits and in the plate adjacent to the welds. The authors recognized that the minimum nitrogen content investigated (0.13%) was too high to be representative of commercial-purity titanium.

Weldability of the various alloy series was evaluated by tensile and bend tests. In the case of the tensile test, the authors reported that the higher strength of the welds forced nearly all deformation to occur outside of the weld. It is important to note in connection with the reported values of oxygen content that vacuum fusion analyses were not made; the values were estimated on the basis of the oxygen present in the sponge plus the amount added.

Although the work summarized above is the only published research known to the authors on the effect of the interstitial elements on the properties of welds in titanium, a limited survey of the literature on the effect

of carbon, oxygen, hydrogen and nitrogen on the structure and properties of iodide and sponge-base titanium is appended.

Materials Investigated and Their Chemical Analyses

The experimental program at the Watertown Arsenal Laboratory was divided into two phases, one for evaluating the tensile properties of welds in $^1/_{10}$-in. sheet and the other for determining the notch toughness and bend ductility of weld deposits in $^1/_4$-in. plate involving various filler and base metal combinations. One of the principal variables of this investigation was the interstitial content of the filler and base metals. Since commercial materials were used, the variations in interstitial content were adventitious.

The chemical composition of the various filler and base metals is reported in Tables 1 and 2. Analysis for the metallic elements and nitrogen was made by Lucius Pitkin, Inc. (Contract No. DA-30-069-ORD-636); and vacuum fusion analysis for oxygen and hydrogen was made by the National Research Corp. (Contract No. DA-19-020-ORD-794). A panel on Methods of Analysis (Army Ordnance Corps Metallurgical Advisory Committee on Titanium) is presently active, comparing the methods and results of various laboratories using controlled samples. A comparison between vacuum fusion analyses for oxygen obtained by eight members of the panel using controlled samples indicated the average deviation from the mean to be of the order of 10%. Results using a sample containing manganese were good in spite of the gettering characteristics of manganese; five cooperators reported values of 0.140, 0.125, 0.122, 0.123 and 0.138% oxygen.

As a check on the homogeneity of the base metals,

Table 1—Chemical Analysis of Filler and Base Metals for Tensile Study

Designation	*Heat No.*	*Interstitial content, wt. %*			
		Carbon	*Oxygen*	*Hydrogen*	*Nitrogen*
	Base metals				
RS-55	422	0.07	0.167	0.0076	0.040
RS-55	423	0.03	0.238	0.0066	0.089
RC-55	5-5059	0.08	0.095	0.0073	0.048
	Filler metals				
Ti-75A	L-914	0.04	0.075	0.0040	0.068
RC-55	5-5032	0.09	0.091	0.0064	0.038
RC-130AW (6.6% Mn)	AW-3615	0.04	0.118	0.0098	0.028
RC-130B (3.8% Mn – 3.5% Al)	B-3267	0.12	0.140	0.0066	0.026
4Cr – 2Mo (3.7% Cr – 2.6% Mo)	L-989	0.08	0.108	0.044*	0.048
Ti-140A (1.9% Cr – 1.8% Mo – 2.2% Fe)	M-302	0.21*	0.157	0.020	0.056

* Average of two determinations.

Table 2—Chemical Analysis of Filler Metals, Base Metals and Deposited Weld Metals, ¼-In. Weldments

Designation	*Heat*	*C*	*O*	*H*	*N*	*Fe*	*Mn*	*Al*	*Cr*	*Mo*
				Base metal chemistry, wt. %						
A*	5-3301	0.08	0.058	0.0066	0.026	0.22	..	..	..	..
B*	M-232	0.07	0.156	0.018	0.023	0.04	..	..	..	..
C		0.24	0.125	0.023	0.038	0.12	..	..	..	..
				Filler metal chemistry, wt. %						
RC-55	5-5032	0.09	0.091	0.0064	0.038	0.20	..	..	..	..
Ti-75A	L-914	0.04	0.075	0.0040	0.068	0.28	..	..	..	..
RC-130AW	AW-3615	0.04	0.118	0.0098	0.028	..	6.59	..	..	..
RC-130B	B-3267	0.12	0.140	0.0066	0.026	..	3.76	3.53	..	..
4Cr – 2Mo	L-989	0.08	0.108	0.044*	0.048	0.30	..	..	3.74	2.63
Ti-140A	M-302	0.21*	0.157	0.020	0.056	2.16	..	..	1.92	1.85
Base metal	*Filler*	*C*	*O*	*H*	*N*	*Fe*	*Mn*	*Al*	*Cr*	*Mo*
				Deposited weld metal chemistry, wt. %						
A	Ti-75A	0.13	...	....	0.044	..	..	..	..	..
	RC-55	0.09	...	....	0.048	..	..	..	..	..
	RC-130AW	0.09	0.131	0.0055	0.062	..	1.84	..	..	..
	RC-130B	0.10	0.125	0.0070	0.028	..	0.72	1.59	..	..
	4Cr – 2Mo	0.14	0.150	0.0065	0.027*	..	..	..	0.47	1.11
	Ti-140A	0.06	0.133	0.010	0.036	1.30	..	..	0.67	1.20
B	Ti-75A	0.08	...	....	0.084	..	..	..	..	..
	RC-55	0.05	...	....	0.056	..	..	..	..	..
	RC-130AW	0.07	0.168	0.0114	0.042	..	2.95	..	..	..
	RC-130B	0.09	0.166*	0.0122*	0.052	..	1.17	1.77	..	..
	4Cr – 2Mo	0.09	0.150	0.0120	0.059*	..	..	..	0.68*	1.12*
	Ti-140A	0.09	...	....	0.052	1.18	..	..	0.85	0.30
C	Ti-75A	0.13	0.130	0.0069	0.052	..	..	..	..	..
	RC-55	0.16	0.152	0.0052	0.024	..	..	..	..	..
	RC-130AW	0.13	0.146	0.014	0.040	..	1.58	..	..	..
	RC-130B	0.13	0.161	0.011	0.036	..	0.97	1.51	..	..
	4Cr – 2Mo	0.15	0.142	0.017	0.054	..	..	..	0.55	0.38
	Ti-140A	0.15	0.158	0.016	0.072	1.36	..	..	0.55	1.05

* Average of two determinations.

Table 3—Plate Homogeneity

Position	*Carbon*	*Oxygen*	*Hydrogen*	*Nitrogen*	*Iron*
Chemistry of "unalloyed" base metal A, wt. %					
1	0.09	0.055	0.0068	0.032	0.18
2	0.06	0.062	0.0064	0.020	0.27
"Unalloyed" base metal B					
1	0.06	0.170	0.018	0.022	0.02
2	0.08	0.143	0.019	0.024	0.06

Reproducibility of vacuum-fusion analysis

Chemistry of 3.7% Cr – 2.6% Mo Filler, wt. %

Determination	*Oxygen*	*Hydrogen*
1	0.108	0.044
2	0.090	0.045

RC-130B (3.75% Mn – 3.53% Al) filler deposited in base metal B

Determination	*Oxygen*	*Hydrogen*
1	0.175	0.0115
2	0.157	0.0128

samples were taken from both ends of the 96-in. lengths of 1/4-in. plate used for base metal in this investigation. The interstitial and iron contents of the two locations in base metals A and B are presented in Table 3. A comparison between analyses for the two positions indicates acceptable homogeneity. As a check on the reproducibility of the vacuum fusion analyses, duplicate samples of a filler material and a weld deposit were submitted for analysis. The duplicate analyses varied by 11 to 18%.

The chemical composition of the welds was determined by milling chips from the deposited weld metal. The boundaries of the weld deposits were determined by polishing and etching both ends of a 2-in. wide section taken from the center of a 1/4-in. thick weldment. Care was taken to confine the machine tool to the actual volume of deposited weld metal. Samples for vacuum-fusion analysis consisted of a 1/8-in. cube taken from the center of the weld deposit (Fig. 2).

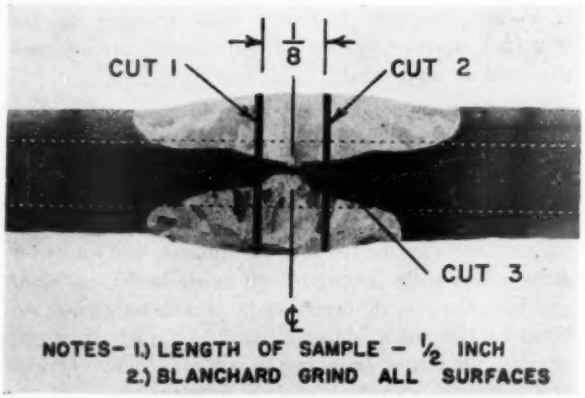


Fig. 2 Weld metal specimen for vacuum fusion analysis

Oxygen and hydrogen content was determined from this specimen by the Walter Technique. The metallic elements, together with carbon and nitrogen, were determined from chips machined from the deposited weld metal. × 3

Questions are anticipated in connection with the homogeneity of the weld metal when alloyed fillers are deposited in "unalloyed" base metal. It is tentatively assumed that as a result of the intense heat and violent agitation produced by the electric arc, the weld puddle is rendered homogeneous except for freezing segregations.* Further observations as to the homo-

* A method of spectrochemical analysis developed at the Watertown Arsenal Laboratory (ref. WAL Report No. 122/32, dated Mar. 12, 1947, by H. J. Levesque and A. Sloan) appears to offer excellent possibilities for resolving questions as to the distribution of metallic elements across a weld deposit. The method permits continuous traverse of a specimen by a spectrographic spark. The sparking is performed on a polished metal surface which may be etched following spectrochemical analysis to show, either in macro- or microphotograph, structural conditions prevailing along the line of traverse of the spectrographic spark. The traverse of the spark is from 0.12-in. (3 mm) to 0.24-in. (6 mm) per run, with each exposure on a spectrum analysis plate representing a distance of 0.006 to 0.012 in. (0.15 to 0.30 mm) on the specimen under examination. The width of spark crater averages 0.015 in. (0.40 mm) and the depth of crater is not over 0.01 in. (0.25 mm). A light polishing, preparatory to etching for microscopic examination, easily removes the surface oxidation caused by sparking; macroscopic etching may be performed without further preparation when immediate correlation of composition and structure is required. Investigations as to the homogeneity of alloy weld deposits in "unalloyed" base metal will be conducted at the Watertown Arsenal Laboratory and reported at a later date.

Table 4—Interstitial Content of Selected Weld Deposits, Wt. %

Base metal A				*Filler metal*				*Weld Deposit*				
C	*O*	*H*	*N*	*C*	*O*	*H*	*N*	*C*	*O*	*H*	*N*	*Total*
				RC-130AW								
0.08	0.058	0.0066	0.026	0.04	0.118	0.0098	0.028	0.09	0.131	0.0055	0.062	0.2885
				RC-130B								
				0.12	0.140	0.0066	0.026	0.10	0.125	0.0070	0.028	0.2600
				4Cr – 2Mo								
				0.08	0.108	0.044	0.048	0.14	0.150	0.0065	0.027	0.3235
				Ti-140A								
				0.21	0.157	0.020	0.056	0.06	0.133	0.010	0.036	0.2390
Base metal B				*Filler metal*				*Weld deposit*				
				RC-130AW								
0.07	0.156	0.018	0.023	0.04	0.118	0.0098	0.028	0.07	0.168	0.0114	0.042	0.2914
				RC-130B								
				0.12	0.140	0.0066	0.026	0.09	0.166	0.0122	0.052	0.3202
				4Cr – 2Mo								
				0.08	0.108	0.044	0.048	0.09	0.150	0.0120	0.059	0.3110
Base metal C				*Filler metal*				*Weld deposit*				
				RC-130AW								
0.24	0.125	0.023	0.038	0.04	0.118	0.0098	0.028	0.13	0.146	0.014	0.040	0.330
				RC-130B								
				0.12	0.140	0.0066	0.026	0.13	0.161	0.011	0.036	0.338
				4Cr – 2Mo								
				0.08	0.108	0.044	0.048	0.15	0.142	0.017	0.054	0.363
				Ti-140A								
				0.21	0.157	0.020	0.056	0.15	0.158	0.016	0.072	0.396

geneity of the weld deposits are made possible by the hardness traverses of the welds (described in a later section).

The chemical analysis for *C*arbon, *O*xygen, *H*ydrogen and *N*itrogen hereinafter will be referred to as the *COHN* and the sum of the four interstitial contents in weight percent will be referred to as the *total COHN*.†

† Combining the four interstitial elements into a single value by adding their respective contents in weight percent should not be construed to signify that all four elements have the same effect on mechanical properties per unit of concentration. The literature (see Appendix) and data obtained in this study all show a decided difference between the interstitial elements in their effect on tensile properties and hardness. When added individually to iodide-purity titanium a concentration of 0.1% of the element raises the hardness and strength approximately as follows: nitrogen 80 to 85%, oxygen 45 to 50%, carbon 25 to 30% and hydrogen 10 to 20%. However, information is not yet available on the relative effects of the interstitial elements on notch toughness.

Table 5—Estimated Interstitial Contents of the Various Weld Deposits

"Unalloyed" filler in "unalloyed" base metal, wt. %

	Carbon	*Oxygen*	*Hydrogen*	*Nitrogen*	*COHN*
Base metal A	0.08	0.058	0.0066	0.026	
Filler RC-55	0.09	0.091	0.0064	0.038	
Average	0.08	0.074	0.0065	0.032	Total 0.1925
Filler Ti-75A	0.04	0.075	0.0040	0.068	
Average	0.06	0.066	0.0053	0.047	Total 0.1783
Base metal B	0.07	0.156	0.018	0.023	
Filler RC-55	0.09	0.091	0.0064	0.038	
Average	0.08	0.124	0.0122	0.030	Total 0.2462
Filler Ti-75A	0.04	0.075	0.0040	0.068	
Average	0.06	0.116	0.0110	0.046	Total 0.2330
Base metal C	0.24	0.125	0.023	0.038	
Filler RC-55	0.09	0.091	0.0064	0.038	
Average	0.16	0.108	0.0147	0.038	Total 0.3207
Filler Ti-75A	0.04	0.075	0.0040	0.068	
Average	0.14	0.100	0.0135	0.053	Total 0.3065

Alloyed filler in "unalloyed" base metal, wt. %

	Carbon	*Oxygen*	*Hydrogen*	*Nitrogen*	*COHN*
Base metal A	0.08	0.058	0.0066	0.026	
Filler RC-130AW	0.04	0.118	0.0098	0.028	
Average	0.06	0.088	0.0082	0.027	Total 0.1832
Filler RC-130B	0.12	0.140	0.0066	0.026	
Average	0.10	0.099	0.0066	0.026	Total 0.2316
Filler 4Cr – 2Mo	0.08	0.108	0.044	0.048	
Average	0.08	0.083	0.0253	0.037	Total 0.2253
Filler Ti-140A	0.21	0.157	0.020	0.056	
Average	0.14	0.108	0.0133	0.041	Total 0.3023
Base metal B	0.07	0.156	0.018	0.023	
Filler RC-130AW	0.04	0.118	0.0098	0.028	
Average	0.06	0.137	0.0139	0.026	Total 0.2369
Filler RC-130B	0.12	0.140	0.0066	0.026	
Average	0.10	0.148	0.0123	0.024	Total 0.2843
Filler 4Cr – 2Mo	0.08	0.108	0.044	0.048	
Average	0.08	0.132	0.031	0.036	Total 0.2790
Filler Ti-140A	0.21	0.157	0.020	0.056	
Average	0.14	0.156	0.019	0.040	Total 0.3550
Base metal C	0.24	0.125	0.023	0.038	
Filler RC-130AW	0.04	0.118	0.0098	0.028	
Average	0.14	0.122	0.0164	0.033	Total 0.3114
Filler RC-130B	0.12	0.140	0.0066	0.026	
Average	0.18	0.132	0.0148	0.032	Total 0.3588
Filler 4Cr – 2Mo	0.08	0.108	0.044	0.048	
Average	0.11	0.116	0.034	0.043	Total 0.3030
Filler Ti-140A	0.21	0.157	0.020	0.056	
Average	0.22	0.141	0.021	0.047	Total 0.4290

Table 6—Comparison Between the Estimated and Actual Gas Contents of Welds in Base Metal C

Filler metal	Hydrogen content, wt. % Estimated*	Actual	Loss	%
Ti-75A	0.014	0.0069	0.007	50
RC-55	0.015	0.0052	0.010	67
RC-130AW	0.016	0.014	0.002	13
RC-130B	0.015	0.011	0.004	27
4Cr – 2Mo	0.034	0.017	0.017	50
Ti-140A	0.021	0.016	0.005	24
Filler metal	**Oxygen content, wt. % Estimated**	**Actual**	**Gain**	**%**
Ti-75A	0.100	0.130	0.030	30
RC-55	0.108	0.152	0.044	41
RC-130AW	0.122	0.146	0.024	20
RC-130B	0.132	0.161	0.029	22
4Cr – 2Mo	0.116	0.142	0.026	22
Ti-140A	0.141	0.158	0.017	12
Filler metal	**Nitrogen content, wt. % Estimated**	**Actual**	**Gain**	**%**
Ti-75A	0.053	0.052	...	..
RC-55	0.038	0.024	...	..
RC-130AW	0.033	0.040	0.007	21
RC-130B	0.032	0.036	0.004	12
4Cr – 2Mo	0.043	0.054	0.011	26
Ti-140A	0.047	0.072	0.025	53

* Estimated value is based on an arithmetical average of the interstitial content of the filler metal and the base metal (see Table 5).

Table 4 presents the COHN in a selected group of alloy weld deposits. Before analyses were made of the weld deposits, it was assumed that the COHN of the welds could be estimated by averaging the interstitial contents of the filler and base metals. The estimation was based on the assumption that approximately equal volumes of filler and base metals were melted by the arc and that nearly perfect shielding would prevent an appreciable increase in the COHN from the air surrounding the inert shield. Table 5 presents the combined interstitial contents of the various filler and base metals as estimated by the method of averaging. In addition to the estimated weight percent for each of the individual interstitial contents, the total estimated COHN is also listed for each filler and base metal combination.

If the assumption is reasonably correct that approximately equal volumes of filler and base metal are melted to form the weld deposit (see Fig. 1), then a comparison between the estimated COHN and the actual COHN should provide an indication of the effectiveness of the inert-gas shield. The macro photographs of three weld areas were measured to provide an indication of the relative volumes of filler and base metal contained in the weld deposits. The percentage of base metal melted ranged from 49 to 64% with an average of 55%. Table 6, compiled from Tables 4 and 5, compares the estimated versus the actual oxygen, nitrogen and hydrogen contents of welds in base metal C. Welds of base metals A and B were not included because they had hand-beveled joint preparation and, consequently, would be expected to show excessive scatter for such a comparison. In the case of hydrogen, Table 6 shows that the value as determined by analysis of the deposited weld metal was either approximately the same or very much less than the estimated hydrogen content. Thus, it appears that hydrogen evolved from the weld during solidification and/or cooling. Oxygen and nitrogen, on the other hand, showed an increase over the estimated value indicating a pickup of these elements during welding.

WELDING PROCEDURE

The weldments for the tensile phase of this work were prepared from $^1/_{10}$-in. thick plate. The welds were made with a 250-amp water-cooled electrode holder containing a $^1/_8$-in. tungsten electrode. The torch was mounted on a radiagraph so that the arc travel speed could be controlled. In addition to the primary inert-gas shield issuing from the electrode holder, a special trailing shield and backing bar were used to protect the weldment during the welding cycle. The trailing shield (Fig. 3)* was essentially a rectangular

* Original trailing shield for this program was loaned to Watertown Arsenal Laboratory through the courtesy of The Murray Hill Laboratory of Air Reduction Sales Co.

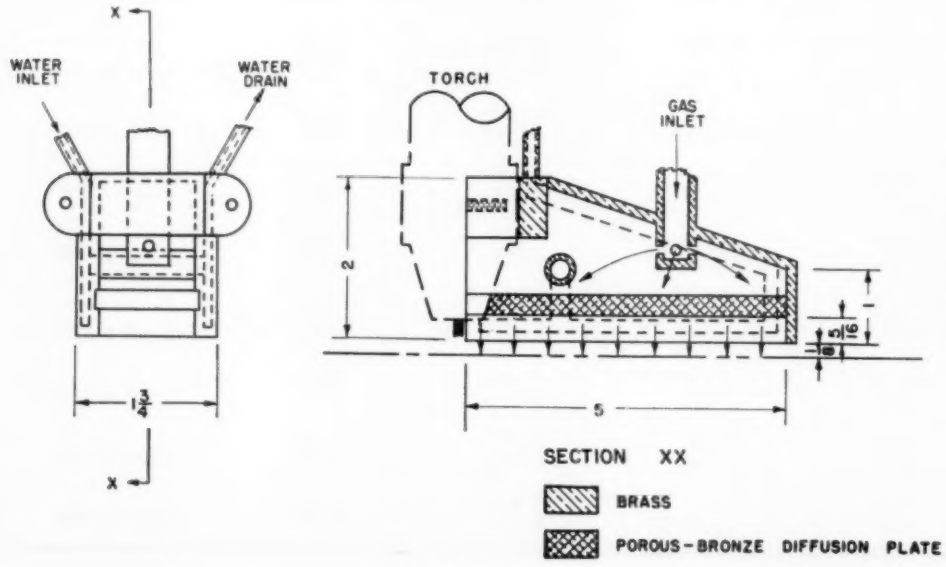


Fig. 3 Trailing shield

Solidifying and/or hot weld metal may be left unprotected by the advancing torch. For example if the travel speed is slow, the cooling rate of the weld deposit is slow and hot metal is left unprotected by the advancing electrode holder. If the weld surface is to be kept bright and free of discoloration, the trail is needed.

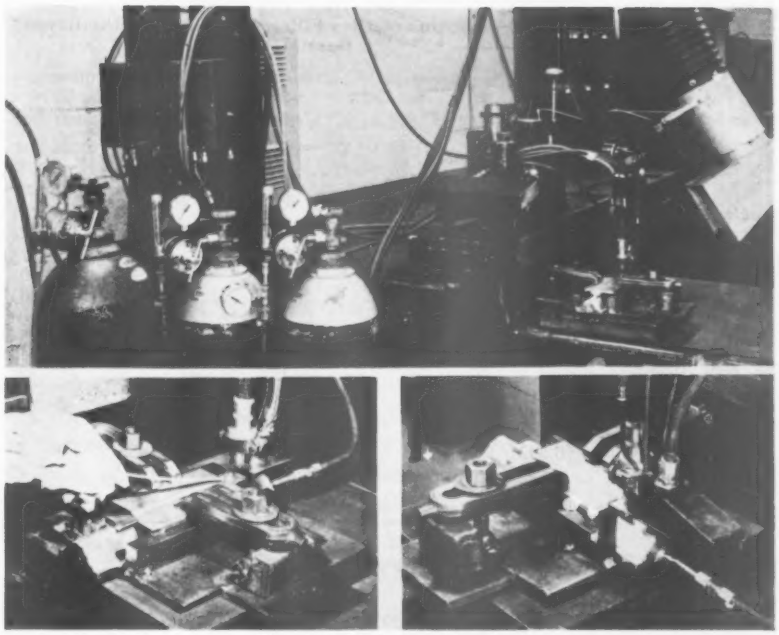


Fig. 4 Welding equipment

A tungsten-electrode holder (manual type) is mounted on a carriage for control of the travel speed. A flow control panel starts the inert gas prior to striking the arc and maintains the flow in both torch and trailing shield for a controlled period after the arc is broken. The filler metal is introduced by hand.

gas chamber, one wall of which consisted of a porous metal plate, acting as a diffusion element. The area of weld so shielded was approximately 2 x 4 in. The underside of the 1/16-in. weldments were protected by a close-fitting grooved copper bar. Details of the welding procedure follow:

Joint design..... Square butt, single pass
Machine settings.. 235 amp, 79 v open and 20–22 v closed circuit voltage, direct current, straight polarity
Arc travel speed.. 12 ipm
Inert-gas shield... Primary, 60 cfh helium using a 9/16-in. ID nozzle
Trail, 50 cfh argon
Backing, grooved copper bar

The weldments for the notch toughness and bend ductility phase of this work were prepared from 1/4-in. plate. A double-V butt joint was used to provide complete symmetry in the weld joint and thereby produce more uniform base metal dilution of the weld joint. At first the joints were hand ground (edges chamfered to 1/16 in., 45 deg), but this later had to be changed to a machined joint to insure more even and complete penetration. As in the case of the 1/10-in. welds, a 250-amp water-cooled electrode holder with a 1/8-in. tungsten mounted on a radiagraph was used. Weld protection was provided by the torch and trailing shield. The underside of the weldment was protected during both the first and second passes by a special copper fixture issuing inert gas through regularly spaced holes (Fig. 4). An improved design of the backing fixture was introduced in the later stage of the investigation which provided more uniform coverage by means of a porous diffusion plate (Fig. 5).

Welds were inspected by X-ray for soundness of joint. Some incomplete penetration and porosity was noted; such weldments were discarded. Visual examination of the surfaces of the weld deposits provided a simple but effective means of determining the adequacy of the gas shielding. The surface of all welds had a bright metallic luster usually silvery, sometimes tinted with gold or blue. Copperbacked welds without underside gas protection invariably developed the metallic gold or blue colors.

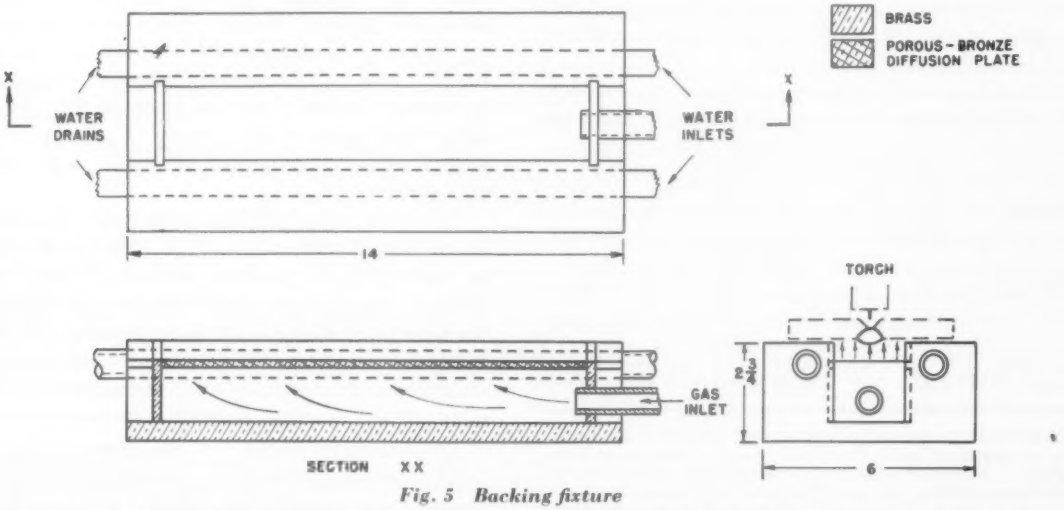


Fig. 5 Backing fixture

A water-cooled support is provided for the weldment, thus preventing a build-up of heat in the fixture. The essential feature of the backing fixture is an inert-gas chamber with a porous diffusion plate to uniformly disperse helium against the underside of the weldment.

Details of the welding procedure for the 1/4-in. weldments follow:

Joint design.....Double-V butt, 2 passes
Machine settings..305–325 amp, 70–75 v open and 25–30 v closed circuit voltage, direct current, straight polarity
Arc travel speed..11–12 ipm
Inert-gas shield...Primary, 60–85 cfh helium using a 9/16-in. ID nozzle
Trail, 50 cfh argon
Backing, 20–50 cfh helium

A low interpass temperature was maintained in all cases (100–200° F). Peak temperatures and phase transformations were investigated in a few weldments. This was done by means of a high-speed temperature recorder and a thermocouple attached to the surface of the first-pass weld while depositing the second pass. The following data were obtained from welds deposited in base metal B:

Filler metal	*Travel speed, ipm*	*Peak temp., ° F*	*Phase trans. ° F*
RC-55	14	1670	1300
	12	1960	1400
4Cr–2Mo	14	1840	1250
	12	2230	...
RC-130B	14	2160	1500

Thus, in depositing the second pass the first pass weld metal was reheated into the beta field. Phase transformation was noted by discontinuities in the cooling curves caused by the evolution of the heat of transformation.

The welding procedure and joint design are obviously important factors in controlling the weld-metal chemistry and resulting properties when joining "unalloyed" base metal with an alloy filler. Two questions which are anticipated in this connection are, first, as to the homogeneity of the weld metal when an alloy filler is deposited in "unalloyed" base metal; and second, as to effect of joint design on the composition of the weld deposit. With regard to the former, it is assumed that as a result of the intense heat and violent agitation produced by the electric arc, the weld puddle is rendered homogeneous except for freezing segregations (hardness traverses of the weld deposits, as described in a later section of this report, provide evidence as to the homogeneity of the weld deposits). With regard to the second question, it is to be expected that joint geometry will control to some degree the amount of base metal melted and, therefore, will control the extent of dilution of the alloy filler metal. Table 7 presents data on the effect of joint geometry on chemical composition. It is apparent that considerable variation in chemical composition is possible by control of the joint design. Table 8 summarizes the dilution of the various alloying elements, as computed from the data reported in Table 2. With the exception of the welds deposited in base metal C, the joints were beveled by hand using an abrasive wheel. The resulting variation in angle and root opening is believed to have caused the variation in dilution when a given filler was deposited in the three base metals. Some of the loss of metallic alloying elements is attributed to vaporization in melting the filler rod. In the case of manganese-bearing alloys, for example, a heavy reddish-brown deposit collects on cold metal parts in the vicinity of the arc; chemical analysis showed the deposit to consist of titanium and manganese oxide.

Table 7—Effect of Joint Design on Weld-Metal Chemistry

Element	*—Machined*—* *Wt. %*	*Dilution, %*	*Hand —Beveled*—* *Wt. %*	*Dilution, %*	*Single-V —70 deg*—* *Wt. %*	*Dilution, %*
RC-130B (3.76% Mn – 3.53% Al) deposited in base metal C						
Manganese	0.97	74	1.32	65	2.58	31
Aluminum	1.51	57	2.72	23	2.61	26
4Cr – 2Mo (3.74% Cr – 2.63% Mo) deposited in base metal C						
Chromium	0.55	85	0.74	80	0.90	76
Molybdenum	0.88	66	0.95	64	1.15	56

* *Hand-beveled joints* were essentially square-butt joints with a 1/16-in. root opening (edges chamfered 1/16-in., 45-deg on an abrasive wheel). *Machine-beveled joints* consisted of a double-V 90-deg included angle with a 1/16-in. land at mid-thickness and a 1/32-in. root opening. *Single-V 70-deg included angle* was also a machined joint with no land or root opening. Two weld passes were used to complete the joint.

Table 8—Dilution of Alloy Fillers Deposited in "Unalloyed" Base Metals

Filler	*Base metal*	*Dilution of alloying —Elements, %— Fe*	*Mn*	*Al*	*Cr*	*Mo*
RC–130B (3.76Mn – 3.53Al)	A	..	81	55	..	..
	B	..	69	50	..	..
	C*	..	74	57	..	..
	Avg		75	54		
4Cr – 2Mo (3.74Cr – 2.63Mo)	A	..	..	..	88	58
	B	..	..	..	82	57
	C*	..	..	..	84	66
	Avg				85	60
Ti-140A (2.16Fe – 1.92Cr – 1.85Mo)	A	40	..	..	65	35
	B	45	..	..	56	84
	C*	37	..	..	71	43
	Avg	41			64	54
RC-130AW (6.59Mn)	A	..	72	..	..	..
	B	..	55	..	..	..
	C*	..	76	..	..	..
	Avg		68			

* Machined joint: double-V 90-deg including angle 1/16-in. land, 1/32-in. root opening.

The areas of melted base metal and deposited weld metal (Fig. 1) were measured for three welds deposited in base metal C (selected because of their machine-beveled edge preparation). It was anticipated that the amount of alloy lost by vaporization could be determined by comparing the alloy content of the deposited weld metal as determined by chemical analysis with the alloy content as calculated using the measured areas:

$$\frac{\text{Alloy content of filler}}{\text{Alloy content of weld}} = \frac{\text{total area of deposit}}{\text{total minus shaded areas}}$$

Table 9 lists the calculated alloy contents versus the actual alloy contents for the three weld deposits. If

Table 9—Loss of Metallic Elements Due to Dilution and Vaporization

Filler	Areas, sq in.		Alloy content, wt %	
	Total	Shaded	Calculated	Actual
RC-130AW	0.616	0.320	3.16 Mn	1.58 Mn
RC-130B	0.684	0.440	1.34 Mn 1.26 Al	0.97 Mn 1.51 Al
Ti-140A	0.676	0.330	1.11 Fe 0.98 Cr 0.95 Mo	1.36 Fe 0.55 Cr 1.05 Mo

alloy is lost by vaporization, the calculated values should be higher than those obtained by actual analysis. It is interesting to note that the metals with the lowest boiling points (manganese and chromium) were consistent in showing a loss, and the metal with the highest boiling point (molybdenum) showed no loss. No explanation is offered for the discrepancy in the case of aluminum and iron (intermediate boiling points).

TEST AND RESULTS

Tensile Testing

The tensile study was performed using three heats of "unalloyed" base metal from two commercial sources. Chemical analyses of the filler and base metals used in the tensile study were listed in Table 1. It may be noted that the base metal heats were similar except for a marked difference in oxygen. Likewise, the interstitial content of the six filler materials were similar except for a marked variation in oxygen content, two instances of exceptionally high hydrogen, and one instance of high carbon.

The tensile properties were determined with the weld joint in two orientations, first with the weld tranverse to the direction of tensile loading and second with the weld longitudinal to the direction of loading. The test specimen (Fig. 6) was a standard flat tensile, 0.500 in. wide, 9 in. long, with a 2-in. gage length. The plate was tested in the as-rolled thickness ($^1/_{10}$ in.) and the welds were tested both with and without weld reinforcement. With the weld oriented longitudinal to the direction of tensile loading and centered in the 0.500-in. wide specimen, a small amount of heat-affected base metal was included in the test.

Figure 7 provides a graphical representation of the tensile-test results in the two heats from a single commercial source. Since little or no difference was observed between the strengths and ductility of specimens tested with and without weld reinforcement, the illustration presents only the data for specimens with the weld reinforcement intact. The data for the transverse welds represent an average of four test specimens and for the longitudinal welds, an average of two test specimens. A marked difference in strength between the two heats of "unalloyed" base metal was noted, with the high-oxygen heat appreciably the higher of the two. Attention is invited to the failure of the transverse-weld tensile tests to differentiate between the various weld and base metal combinations. Of the 24 weldments tested, all but three failed in the base metal approximately midway between the weld deposit and the shoulder of the tensile specimen (the three exceptions are deemed significant in that they occurred in the heat-affected zones of welds in which the "unalloyed" filler was deposited in the high-oxygen base metal). The fact that deformation and failure generally occurred in the base metal was the result of the higher flow strength of the weld deposit; and, consequently, the indicated strength level was independent of the strength of weld joint *per se*. On the other hand, with the weld longitudinal to the direction of loading and centered in the $^1/_2$-in. wide tensile specimen, the entire joint including weld metal and heat-affected zone was subjected to uniform straining irrespective of the relative flow strengths of the various components of the joint. Thus, in the weld-longitudinal tensile test a marked variation in properties was observed for the various weld and base metal combinations. The alloy filler metals, in particular, produced an appreciable increase in strength.

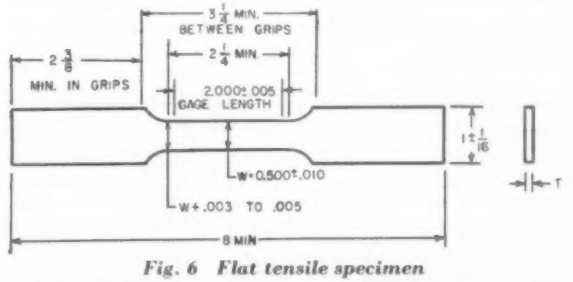


Fig. 6 Flat tensile specimen

Welds are tested either longitudinal or transverse to the length of the specimen. When tested in the longitudinal direction, the weld is centered in the 0.50-in. wide section; a small controlled amount of weld heat-affected zone is thereby included in the test.

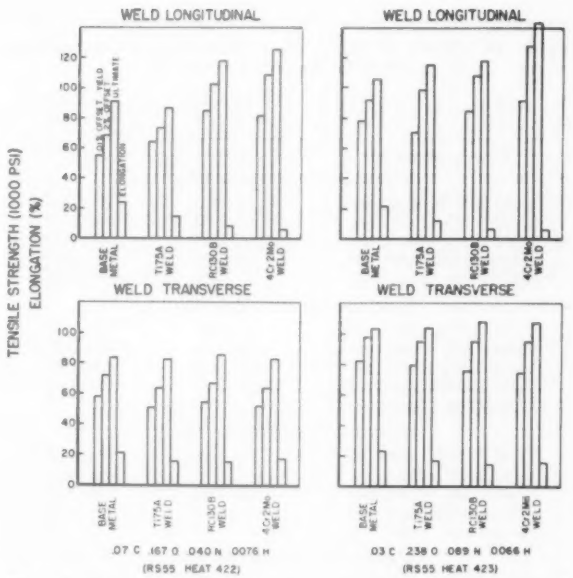


Fig. 7 Tensile test results on two consecutive heats of "unalloyed" titanium

The marked strengthening effect of nitrogen and oxygen on the base metal is shown together with the increased tensile strength of weld joints obtained by the use of alpha-beta alloys as filler metal. The inadequacy of transverse-welded specimens in showing the tensile strength of a weld joint is demonstrated.

Table 10—Effect of Base Metal Interstitial Content on as-Welded Tensile Properties

Tensile properties	*"Unalloyed" heat 422 (0.167% O – 0.040% N)*	*"Unalloyed" heat 423 (0.238% O – 0.089% N)*
Unwelded tensile properties		
Yield 0.01% offset, psi	55,000	78,200
Yield 0.1% offset, psi	65,200	89,800
Yield 0.2% offset, psi	68,200	92,500
Ultimate strength, psi	90,200	105,200
Elongation (2-in.), %	24	22
Welded with RC-130B filler*		
Yield 0.01% offset, psi	84,450	85,600
Yield 0.1% offset, psi	98,700	104,100
Yield 0.2% offset, psi	102,500	108,050
Ultimate strength, psi	117,250	118,650
Elongation (2-in.), %	8	7
Welded with 4Cr – 2Mo filler*		
Yield 0.01% offset, psi	81,150	91,450
Yield 0.1% offset, psi	101,900	120,500
Yield 0.2% offset, psi	108,700	128,350
Ultimate strength, psi	124,550	143,350
Elongation (2-in.), %	6	6
Welded with RC-130AW filler*		
Yield 0.01% offset, psi	74,700	93,000
Yield 0.1% offset, psi	88,000	108,000
Yield 0.2% offset, psi	92,300	113,700
Ultimate strength, psi	106,500	128,500
Elongation (2-in.), %	7	8
Welded with Ti-140A filler*		
Yield 0.01% offset, psi	73,900	
Yield 0.1% offset, psi	96,050	Insufficient
Yield 0.2% offset, psi	101,700	material
Ultimate strength, psi	118,500	
Elongation (2-in.), %	6	

* Average of duplicate test specimens; weld joint longitudinal to direction of tensile loading.

It is concluded from Fig. 7 that tensile properties obtained from a specimen containing a weld transverse to the direction of tensile loading do not reflect the properties of the weld joint because of the generally greater flow strength of weld. An important exception may occur when the level of interstitials in the deposited weld metal or heat-affected zone is sufficient to cause severe embrittlement, in which case the tensile specimen may fail prematurely in the weld or heat-affected zone. Generally, however, for an evaluation of the strength of a given weld joint, it is necessary to test with the weld oriented longitudinal to the direction of tensile loading

Additional alloy filler metals were investigated using the "unalloyed" base metal heats 422 and 423, with the weld joint longitudinal to the direction of tensile loading The tensile properties are summarized in Table 10. From Table 10 and Fig. 7 it may be seen that the higher interstitial content of base metal 423 resulted in a marked increase in strength, particularly, yield strength

Table 11—Increase in Strength Produced by the Interstitial Content of Base Metal and the Use of Alloy Filler Metals

Properties	*Increase in strength, %*		
	Heat 422 vs. 423 (welded)	*Welded vs. unwelded*	
		422	*423*
Welded with RC-130B filler			
Proportional limit	1	54	10
0.2% offset yield	5	50	17
Ultimate strength	1	30	13
Welded with 4Cr – 2Mo filler			
Proportional limit	13	48	17
0.2% offset yield	18	59	39
Ultimate strength	15	38	36
Welded with RC-130AW filler			
Proportional limit	24	36	19
0.2% offset yield	23	35	23
Ultimate strength	21	18	22

(18% increase in ultimate, 36% increase in 0.2 offset yield, and 42% increase in proportional limit). After welding the difference in strength between the two base metals was not nearly as marked, however (see Table 11), particularly when RC-130B was used as a filler. It may be significant in this connection that the filler metals with the highest COHN (RC-130B: 0.2926%; 4Cr–2Mo: 0.2800%) resulted in less difference in strength between welds in base metals 422 and 423 than the filler with the lowest COHN (RC-130AW: 0.1958%). Table 11 summarizes the effect, percentagewise, of the base metal interstitial content on the strength of weld joint, and also the percent increase in strength of alloyed weld joints over the "unalloyed" base metals. In general, an appreciably greater increase in strength was realized by the use of alloy fillers in the base metal of lower interstitial content. Although the average tensile elongation was 70% lower in the welded tensile specimens than in the unwelded specimens, it is interesting to note (Table 10) the small difference in elongation between welds in base metal heats 422 and 423. Thus, tensile elongation appears to be insensitive to large differences in interstitial content.

Table 12 presents tensile data for alloy welds deposited in a relatively pure base metal (0.2303% COHN as compared with the 0.2846% COHN of base metal 422). Using alloy fillers the proportional limit was increased by 8 to 18%; the 0.2% offset yield strength was increased by 17 to 29%; and the ultimate tensile strength was increased by 25 to 38%. Although the average tensile elongation was decreased 52% by welding, the as-welded tensile ductility, nevertheless, appeared adequate.

Table 12—Strengthening Effect of Alloy Fillers Deposited in "Unalloyed" Base Metal

*Tensile Properties**	*"Unalloyed" Heat 5.5059 (unwelded)*	*RC-130AW*		*RC-130B*		*4Cr – 2Mo*		*Ti-140A*	
		Strength	*Gain, %*	*Strength*	*Gain, %*	*Strength*	*Gain, %*	*Strength*	*Gain, %*
Proportional limit, psi	67,800	75,500	11	80,100	18	73,350	8	75,100	11
0.1% offset yield, psi	76,200	93,050	22	90,150	18	86,400	13	95,050	25
0.2% offset yield, psi	78,000	97,050	24	92,850	19	91,250	17	100,550	29
Ultimate strength, psi	86,000	112,200	30	107,600	25	109,150	27	118,500	38
Elongation (2-in.), %	23.2	11.0	..	11.7	..	10.0	..	11.2	..

* Average of duplicate test specimens; weld joint longitudinal to direction of tensile loading.

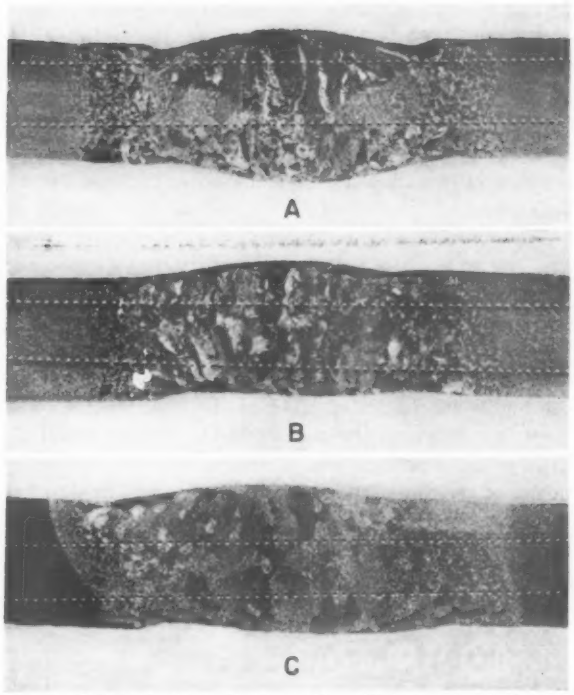


Fig. 8 RC-55 deposited in "unalloyed" base metals A, B, C

Macrophotographs (mag. 3 ×) show the weld deposits and the 10-kg Vickers indents of the hardness traverses. Note that in the case of the weld in base metal A one traverse nearly missed the weld deposit; this accounts for the marked difference between the hardness plots for the two passes shown in Fig. 9. Note also the absence of a fusion line defining the weld deposits.

Hardness Testing

Vickers hardness surveys (10-kg load) were made across each weld in $^1/_4$-in. plate. Impressions were placed at 0.02-in. intervals starting in the unaffected base metal on one side of the deposit and traversing the weld in a line approximately $^1/_{16}$ in. below the surface of the plate. Two such traverses (designated Row 1 and Row 2) were made, one through each of the two weld-passes (Figs. 8–19).

Table 13 summarizes the hardness data with comparisons between the weld metals and the various weld and base metal combinations. Marked differences in weld hardness between the Row 1 and Row 2 traverses

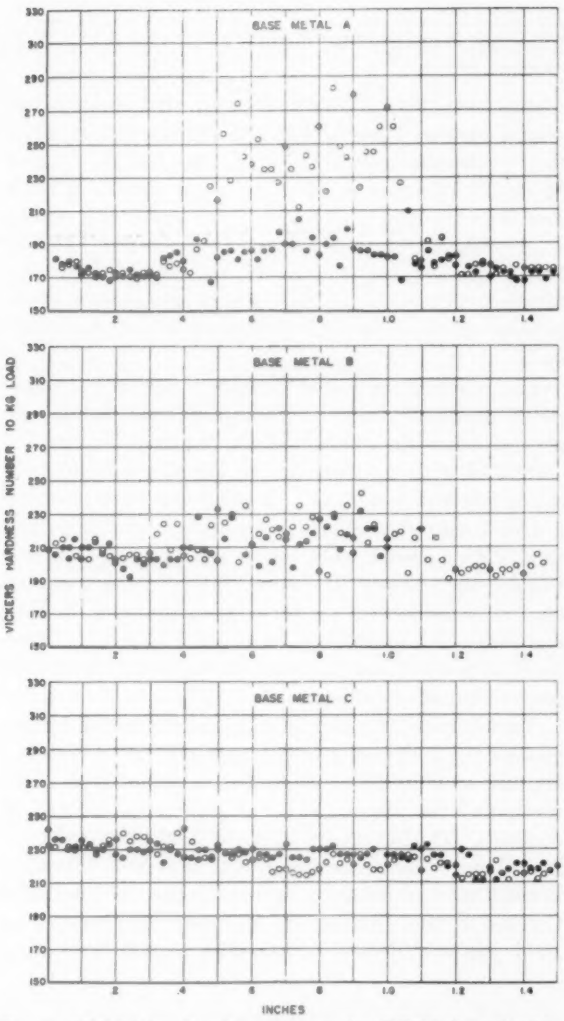


Fig. 9 Weld joint hardness survey for RC-55 deposited in "unalloyed" base metals A, B, C

An appreciable difference in hardness between the base metals is shown, together with a marked difference between the welds produced by a given filler deposited in the three base metals.

were noted in some combinations.* Unfortunately,

* Another general observation which may be of fundamental significance is that there were several cases of a gradient of hardness in the "unalloyed"

Table 13—Summary of Hardness Surveys

	Vickers hardness (10-kg. load) of weld deposits — Base metal			*Increase in hardness of weld over that of base metal* — Base metal			*Difference between welds in various base metals* — Base metal		
Filler metal	*A* 175 Vhn	*B* 195 Vhn	*C* 220 Vhn	*A*	*B*	*C*	*B-A*	*B-C*	*C-A*
RC-55	245	216–220	220–228	70	21– 25	0– 8	...	...	...
Ti-75A	219–229	218–227	218–224	44–54	23– 32	0– 4	...	...	...
RC-130AW	243–271	287–298	268–270	68–96	92–103	48–50	44–27	19–28	25– 0
RC-130B	215–252	260–275	254–278	40–77	65– 80	34–58	45–23	6– 0	39–26
4Cr – 2Mo	244–251	281–285	258–272	69–76	86– 90	38–52	37–34	23–13	14–21
Ti-140A	255–258	288–299	278–286	80–83	93–104	58–66	33–41	10–13	23–28
Column*	a	b	c	d	e	f	g	h	i

* Column a—Reports the average weld metal hardness in base metal A for each of two hardness traverses (one traverse for each weld pass); column b, weld hardness in base metal B; and column c, weld hardness in base metal C. Column d—Reports the difference in hardness between weld metal and base metal for the two hardness traverses in base metal A; column e, in base metal B; and column f, in base metal C (e.g., in the case of RC-130B filler, the difference in hardness between the deposited weld metal and base metal A is 215 minus 175 for the one traverse and 252 minus 175 for the other traverse). Column g—Reports the difference in hardness between welds in base metals A and B using a given alloy filler; column h, in base metals B and C; and column i, in base metals C and A (e.g., with RC-130B filler, the difference in hardness between the weld deposits in base metals A and B is 260 minus 215 and 275 minus 252.

heat-affected zone where hardness values within the HAZ contiguous to the weld equaled the hardness of the alloyed weld deposit. The complexities of weld HAZ are beyond the scope of this investigation and, therefore, will not be considered in this report. The gradient may be a subject for future investigation, however.

control over this variable was lost in that the first and second pass weld metal was not identified in marking the weldments preparatory to machining. ("Post Mortem" attempts to correlate the variation in hardness between Row 1 and Row 2 traverses with scatter in the Charpy data were also unsuccessful. It was noted, however, that in some filler and base metal combinations there was a difference in the appearance of the fracture surfaces between first- and second-pass weld metal.)

The hardness traverses provide evidence regarding the homogeneity of the deposited weld metal. In general, when the location of the hardness indents was correlated with their position in the macroetched weld deposit, it was found that wherever a marked hardness gradient existed it coincided with the fusion zone, and that the deposited weld metal was more or less uniformly hard across its entire traverse. In some instances, considerable scatter was encountered, indicating a lack of homogeneity from grain to grain. However, in general, marked scatter was confined to only one of the two weld passes.

Tensile tests of welds in $^1/_{10}$-in. base metal demonstrated the increased strength that may be realized by the use of alloy fillers deposited in "unalloyed" base metal and the marked effect of base metal interstitial content. The hardness surveys of the various weld and base metal combinations in $^1/_4$-in. plate also indicate a decided strengthening by the use of alloy weld deposits. Studies of the distribution of plastic deformation in weld joints subjected to balanced biaxial tension reported elsewhere[4, 5] have demonstrated the advantages of an overmatching flow strength in the weld metal when attended by notch toughness. Differences in hardness between weld and base metal of 34 to 104 Vickers hardness numbers resulted from the use of alloy filler metals, as compared with differences of 0 to 70 Vhn in the case of "unalloyed" fillers deposited in "unalloyed" base metal.

The overmatching hardness of the "unalloyed" weld deposits in base metal B was unexpected (Table 13, Column e) because the filler metals had a lower interstitial content than the base metal. The higher hardnesses in the case of the "unalloyed" weld deposits in base metal A were to be expected, however, because of the higher interstitial content of the filler metals. On the other hand, in the case of welds in base metal C, little or no difference was observed between the hardnesses of the "unalloyed" weld deposits and base metal C in spite of the appreciably lower total interstitial content of the filler metals (Table 13 Column f). This is explained in part by the fact that carbon is not as

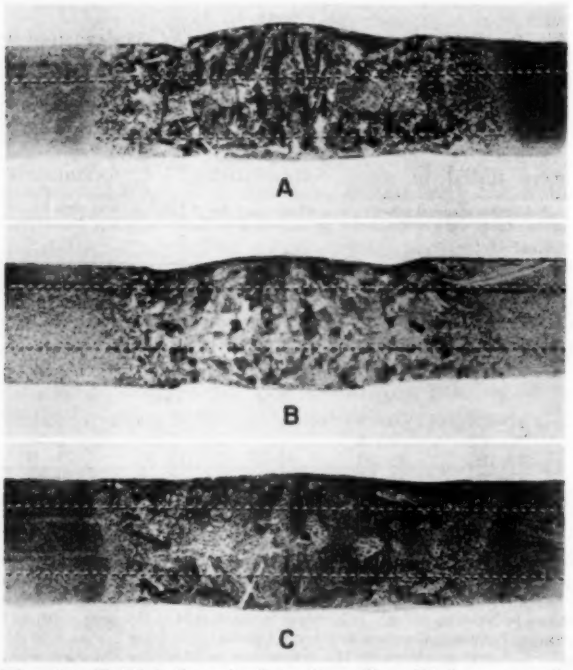


Fig. 10 Ti-75A deposited in "unalloyed" base metals A, B, C

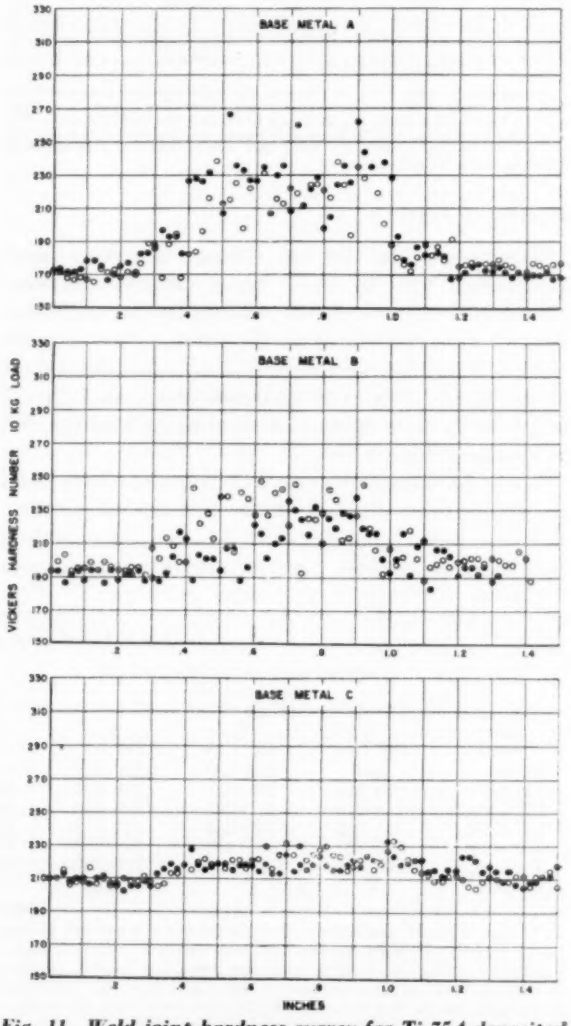


Fig. 11 Weld joint hardness survey for Ti-75A deposited in "unalloyed" base metals A, B, C

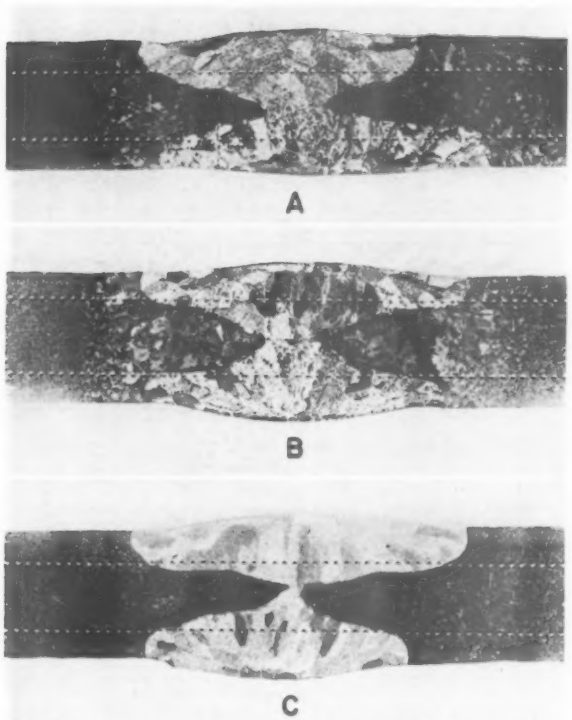


Fig. 12 RC-130AW deposited in "unalloyed" base metals A, B, C

Macrophotographs (mag. 3 ×) clearly show the limits of the alloy-weld deposit.

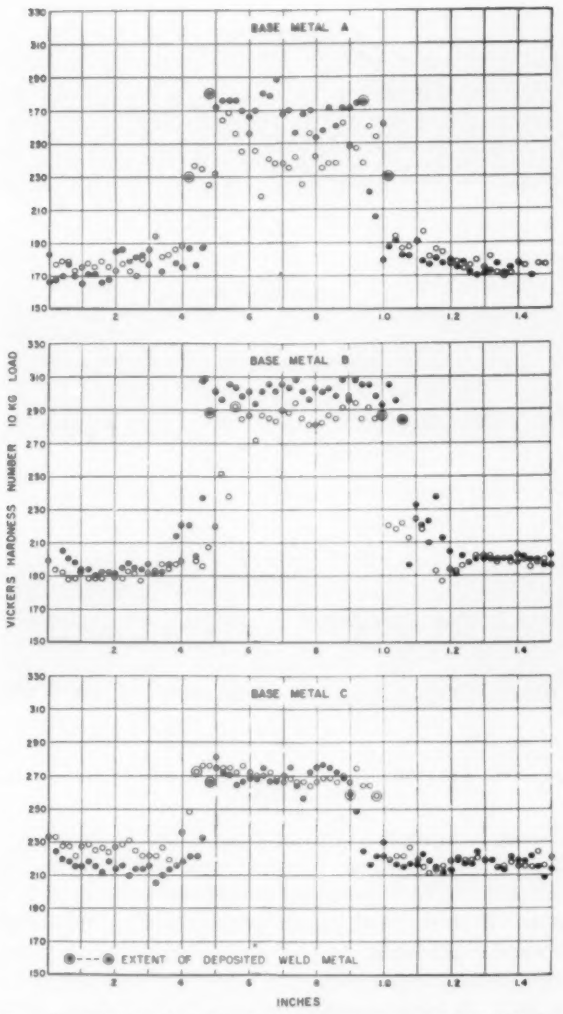


Fig. 13 Weld joint hardness survey for RC-130AW deposited in "unalloyed" base metals A, B, C

The strengthening effect of alloy filler metal is evident. There is, however, a marked difference between welds produced by a given filler when deposited in the different base metals. Note the remarkably uniform hardness from fusion line to fusion line of the weld deposits in base metals B and C.

effective a hardening agent as nitrogen and oxygen. Differences were also observed between the hardnesses obtained with a given filler when deposited in the three base metals (Table 13, Columns g, h and i). Alloy filler metals deposited in base metal B were consistently harder than the same filler deposited in base metal A. This observation is consistent with the higher interstitial content of base metal B. However, when the same alloy fillers were deposited in base metal C, the welds in B were equal or higher in hardness than welds in C, in spite of the higher total interstitial content of base metal C. This confirms the observation of other investigators that carbon is less effective as a hardener or strengthener than nitrogen or oxygen.

Thus, the hardness of weld deposits produced by the various filler and base metal combinations further demonstrates the marked effect that base metal interstitial content has upon the mechanical properties of weld deposits in titanium.

Bend Testing

Bend tests were made on welded joints to determine their bend ductility. The bend test consisted of a specimen 0.2 in. thick and 0.5 in. wide tested over a 2-in. span with a 0.4-in. diam mandrel applied to the weld at midspan. The weld joint was transverse to the bending stresses.

Prior to the selection of the 0.4-in. diam mandrel (1T bend radius), a series of preliminary bend tests were made using different mandrel sizes. To permit a comparison between theoretical and actual elongations in the tension surface of the bend bar, a series of Vickers hardness indents were placed at regular intervals (0.02 in.) across the weld to serve as gage marks. The theoretical elongation in percent was calculated from the following expression:

$$\text{Percent elongation} = y/R_c \cdot 100$$

where

y = $^1/_2$ thickness of bend bar
R_c = radius of curvature
= radius of mandrel plus $^1/_2$ thickness of bend bar

Thus, a 0.4-in. diam mandrel should develop approximately 33.3% elongation in a 0.2-in. thick bend bar. The preliminary tests (Table 14) showed the calculated and measured elongation to check very closely provided: (1) the strain was measured over a short gage length, (2) a critical bend angle was not exceeded and (3) tests were conducted at room temperature. The alloy weld

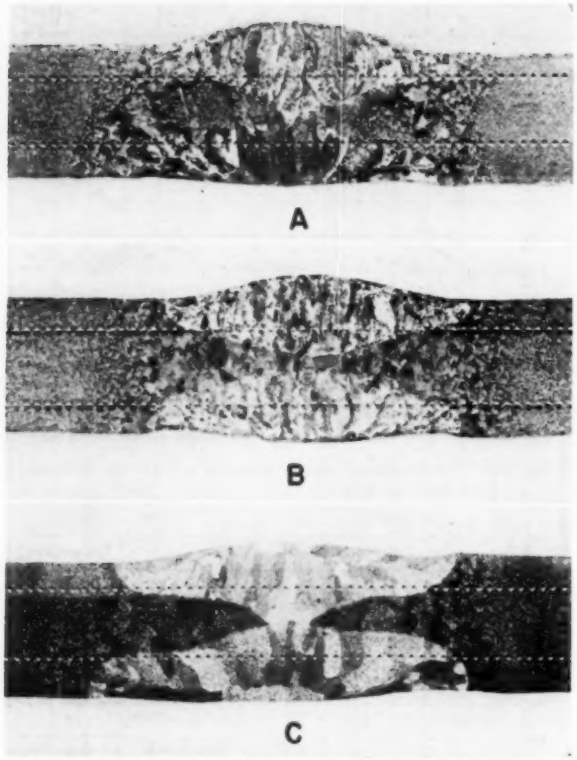


Fig. 14 RC-130B deposited in "unalloyed" base metals A, B, C

deposits required a greater bend angle to reach the theoretical elongation; therefore, the "unalloyed" welds were bent to 75 ± 5 deg and the alloyed welds, to 90 ± 5 deg. If these bend angles were exceeded, the bend specimen gradually developed a lesser curvature than that of the mandrel and, thus, a greater-than-calculated strain. At subzero temperatures, the actual elongations were found to be somewhat less than the calculated value at the maximum deflection permitted by the bend fixture (approximately 100 deg bend angle). Thus, bending over a 1T radius represents a severe test involving strains of the order of 30% elongation.

Six filler metals deposited in base metals A and B were tested at two testing temperatures, viz., 0 and −40° C (Table 15). All welds in base metal A (base metal with the lowest COHN: 0.1706% as opposed to 0.2670% in base metal B) including the two "unalloyed" filler metals withstood the full bend angle (30% elongation or

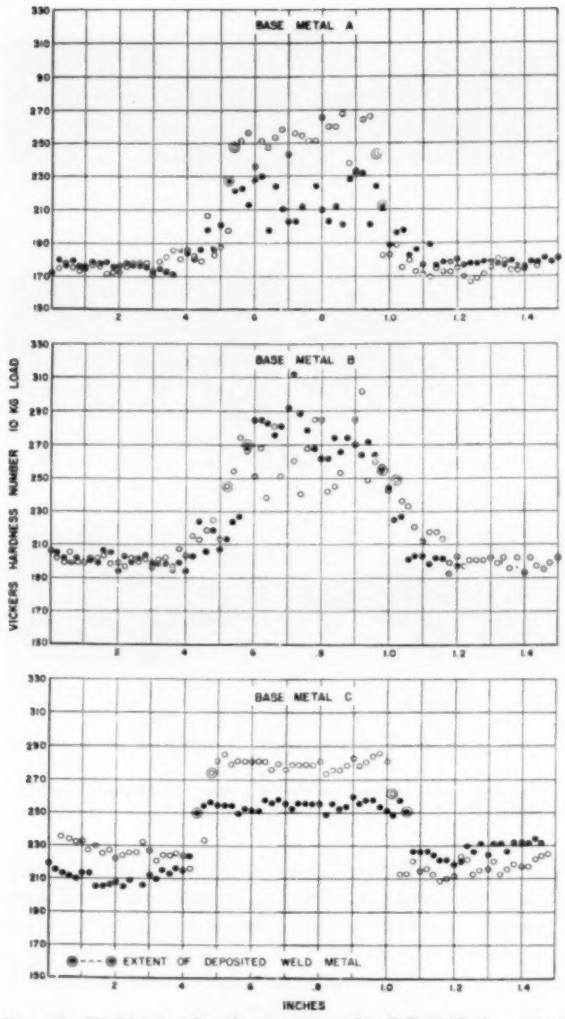


Fig. 15 Weld joint hardness survey for RC-130B deposited in "unalloyed" base metals A, B, C

greater) without fracturing. In fact, of the 22 welded base-metal A bend specimens tested, only three showed evidence of cracking, one with "unalloyed" filler and two with alloyed fillers (tested at −40°). The higher maximum loads required to bend the alloyed welds demonstrate the appreciably greater strengths developed by the low-alloy weld deposits. The higher loads required to bend at −40° as compared to 0° C were also noteworthy.

Table 14—Comparison Between Calculated and Actual Elongations in Guided-Bend Tests

Filler	*Testing Temp., ° C*	*Mandrel radius, in.*	*Maximum load, lb*	*Angle, deg*	*Calc. elong., %*	*Measured elong., % 0.1-gage*	*0.6-gage*
RC-55	25	0.25	940	51*	28.6	29†	17
	25	0.20	880	77*	33.3	33	24
	− 40	0.20	1170	94*	33.3	40	28
	− 65	0.20	1170	92*	33.3	40	30
RC-130B	25	0.25	1245	100*	28.6	29	21
	25	0.20	1210	100*	33.3	29	22
	− 40	0.20	1470	96	33.3	26	19
	−100	0.20	1650	96	33.3	20	18

* Loading was interrupted at regular intervals for strain measurement; loading to greater bend angles than those indicated resulted in the specimen pulling away from the mandrel and, therefore, greater-than-calculated elongation.

† Vickers hardness indents were spaced at 0.02-in. intervals in the tension surface of the bend specimen to serve as gage marks.

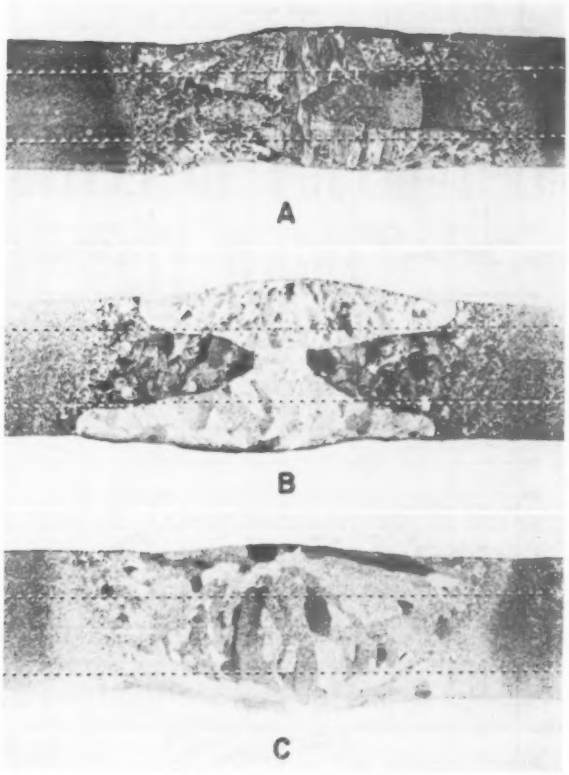


Fig. 16 4 Cr – 2Mo deposited in "unalloyed" base metals A, B, C,

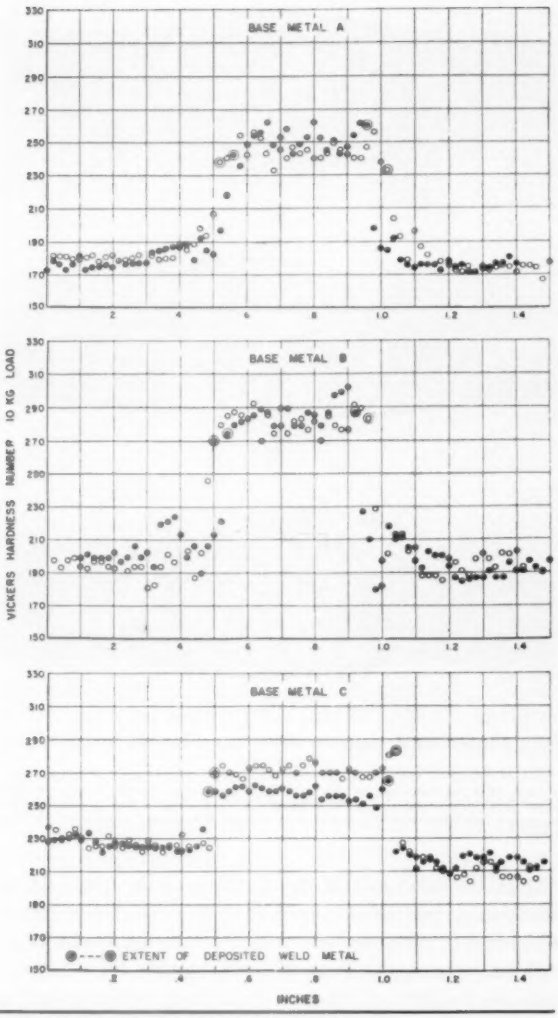


Fig. 17 (right) Weld joint hardness survey for 4Cr – 2Mo deposited in "unalloyed" base metals A, B, C

Table 15—Bend Ductility of Weld Deposits in "Unalloyed" Base Metals A and B

	Base metal A			Base metal B		
Testing temp., ° C	*Filler metal*	*Bend angle, deg*	*Maximum load, lb*	*Filler metal*	*Bend angle, deg*	*Maximum load, lb*
0	Ti-75A	95	1120	Ti-75A	59*	1235
		92	1100		64*	1175
−40		74*	1225		48*	1310
		76	1215		40*	1280
0	RC-55	86	1020	RC-55	85	1105
		89	1010		75*	1160
−40		94	1170		55*	1280
					57*	1260
0	RC-130AW	90	1330	RC-130AW	90	1525
		90	1320		67*	1520
−40		87	1550		70†	1725
		85*	1555		50*	1710
0	RC-130B	91	1300	RC-130B	94	1445
		90	1345		87	1450
−40		96	1470		51‡	1600
					61‡	1640
0	4Cr – 2Mo	90	1400	4Cr – 2Mo	76†	1560
		90	1350		76†	1540
−40		95	1560		45†	1640
		66*	1475		60†	1675
0	Ti-140A	92	1370	Ti-140A	87	1555
		93	1325		86	1555
−40		95	1600		71†	1650
		91	1565		64†	1635

The test specimen was bent until there was a sudden drop in load which was taken to indicate the occurrence of a crack, or until a predetermined bend angle was reached (75° ± 5 for "unalloyed" filler and 90° ± 5 for alloyed filler).

* Slight cracking.

† Extreme cracking.

‡ Fracture of test specimen.

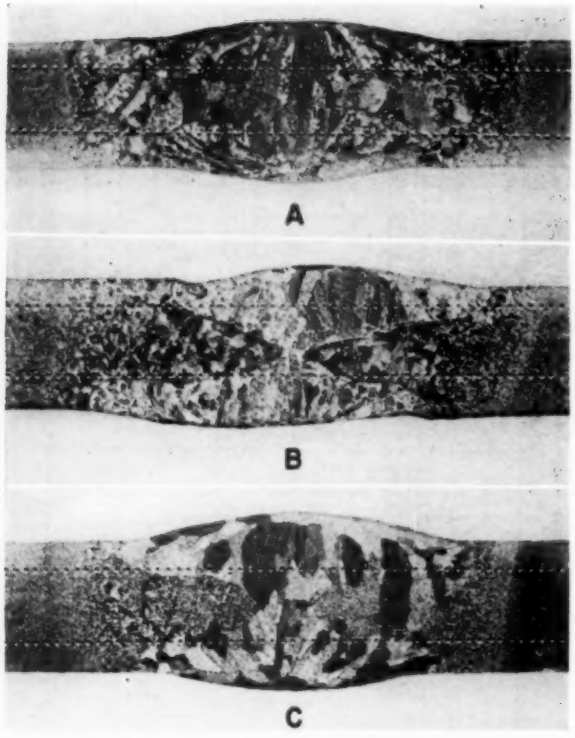


Fig. 18 Ti-140A deposited in "unalloyed" base metals A, B, C

Note that in the case of the weld in base metal B, one hardness traverse nearly missed the weld deposit; this accounts for the difference between the hardness traverses of the corresponding weld passes in Fig. 19.

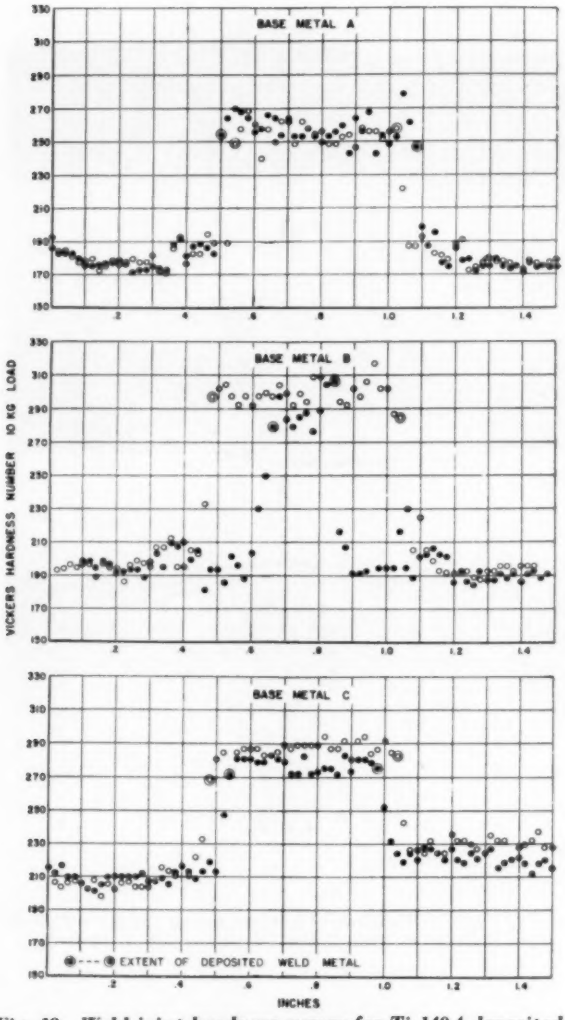


Fig. 19 Weld joint hardness survey for Ti-140A deposited in "unalloyed" base metals A, B, C

The six filler metals deposited in base metal B all cracked or fractured before the theoretical elongation was reached when tested at −40°. Out of a total of 24 welded base-metal B specimens tested, only six developed the 30% theoretical elongation without failing and these occurred at 0° C. Thus, the bend test results show the marked influence of base-metal interstitial content on the bend ductility of welded joints. However, the bend test did not indicate a severe embrittlement in that only two of the 21 specimens which developed cracking actually fractured, and they could not be considered brittle because they underwent 50 to 60 deg of bend angle prior to failure. Fracture, when it did occur, appeared to initiate in the heat-affected zone of the weld.

The instances of heat-affected zone failure illustrate a basic weakness in this type of bend testing. Theoretically, as soon as sufficient load has been applied to produce a curvature in the bend specimen equal to that of the mandrel, the theoretical strain is developed in the outer fibers of the specimen (33.3% elongation with a 1T bend radius). However, the gage length over which the theoretical strain initially occurs is very small. As the bend angle is increased the magnitude of the strain is unchanged, but the gage length over which the theoretical strain occurs increases with the increasing bend angle. Finally, a bend angle is reached at which the bar pulls away from the mandrel, i.e., develops a lesser radius of curvature than the mandrel; from this point on, the theoretical strain is exceeded. Thus, with the mandrel centered on and in contact with a transverse weld joint, the maximum stress is exerted in the weld metal. However, as the volume of plastically deformed metal increases in a lateral direction, a bend angle is reached at which the heat-affected zone of the weld is included in the volume of strained metal. Thus, if the heat-affected zone is weak or brittle, failure may suddenly occur after an appreciable bend angle has been developed. The site of first separation is often difficult to determine and, therefore, the bend test may lead to erroneous conclusions.

References

1. Faulkner, G. E., Grable, G. B., and Voldrich, C. B., Ordnance Contract No. DA-33-019-ORD-231, Summary Report WAL 401/97-18, dated Jan. 30, 1953.
2. *Ibid.*, Interim Report WAL 401/97-27, dated July 31, 1953.
3. Martin, D. C., "Effects of Carbon, Oxygen and Nitrogen on Welds in Titanium," The Welding Journal, 32 (3), Research Suppl., 139-s (1953).
4. Hartbower, C. E., and Pellini, W. S., "Explosion Bulge Test Studies of the Deformation of Weldments," *Ibid.*, 30 (6), Research Suppl., 307-s to 318-s (1951).
5. Hartbower, C. E., and Pellini, W. S., "Investigation of Factors which Determine the Performance of Weldments," *Ibid.*, 30 (10), Research Suppl., 499-s to 511-s (1951).

Effect of Thermal Activation on Fatigue Life of Butt Welds

Thermal activation following overstress does not appear to affect the fatigue life of submerged-arc butt welds

by A. M. Freudenthal and R. A. Heller

OBJECT OF THE INVESTIGATION

THE results are presented of an investigation of the effect of rest periods at moderately elevated temperatures on the fatigue life of butt-welded mild steel specimens, particularly if such rest periods are applied after periods of more or less severe overstressing. The existing evidence concerning this effect on the fatigue life of nonwelded metal specimens is somewhat controversial, though it is at present recognized that, at least for steel, some beneficial influence may be expected if the temperature of the rest period is sufficiently high to produce some relief of the textural (microresidual) stresses which have been produced in fatigue by thermal activation of small groups of particles, but not high enough to intensify this process to such a degree as to produce, during the rest period, definite changes in the structure of the metal, such as (even slight), recrystallization. Since it is well known that high textural stresses are built up in the weld-affected zone, there was reason to assume that such thermal activation, by relieving not only the textural stresses due to repeated loading, but also, to some extent, the textural stresses due to welding which constitute potential nuclei of fatigue damage, would be more effective in extending the life of welded steel specimens than that of unwelded specimens.

This investigation was undertaken to test the validity of this assumption with respect to butt welds.

HISTORY OF THE PROBLEM AND PREVIOUS INVESTIGATIONS

The effect of intermitten[t] rest periods interrupting the sequence of fatigue loading on the fatigue life of carbon-steel structural elements and connections has been a subject of interest for a number of years. However, investigations of this effect have been few, and rather limited in scope; their results are therefore suggestive rather than conclusive.

The earliest indication of what appeared to be an effect of intermittent rest periods on fatigue life came from mining practice. Steel ropes used in mine hoists are designed for a limited life: after a certain period of service individual wires start breaking; the number of wire breakages per unit time of observation gradually increases until the critical condition is reached at which replacement of the rope is mandatory. Comparison of long- and short-lived ropes, involving a very thorough and careful investigation of material properties and operating conditions, leads to the conclusion that the observed substantial differences in the life of ropes of identical properties subject to operating conditions similar in all respects but "density of operation," that is, frequency of loading, could only be caused by this difference in frequency which reduces the intervals between the consecutive loadings and thus the average duration of the intermittent "rest periods"; ropes with high "density of operation" showed a shorter life in terms of load repetitions than those with low density.

Bending fatigue tests[1] of 3 types of cold-drawn carbon-steel wires with 0.7 and 0.8% C, different heat treatment, a yield stress of about 220,000 psi, ultimate tensile strength between 230,000 and 250,000 psi and endurance limit between 45,000 and 37,000 psi were performed at a stress level of about ±80,000 psi. The mean life in uninterrupted tests, determined from 10 specimens for each wire type was found to vary between $N = 56{,}000$ and 65,000 cycles. Interruption of the tests after every tenth of the expected average life by rest periods of, respectively, $^1/_2$ day and 3 days' duration increased the average fatigue life by, respectively, 42 and 50%. The investigation thus showed a definite influence of intermittent rest periods. The effect was found to be most pronounced in coarse-grained ferritic steels; it could be significantly reduced by reducing the number of rest periods through an increase of the length of the loading periods to one-fifth of the expected average life in uninterrupted tests.

A. M. Freudenthal and **R. A. Heller** are with the Department of Civil Engineering, Columbia University, New York, N. Y.

Presented at the AWS National Spring Meeting held in Buffalo, N. Y., May 4–7, 1954.

Results of subsequent rotating beam fatigue tests of 0.31-in. diam specimens of the German low-carbon-manganese steels St.37 and St.60, intermittently interrupted by rest periods at elevated temperatures of 140° C, support the assumption that the effect of rest periods on fatigue life might be due to relaxation of nuclei of potential fatigue damage produced by fatigue loading; these damaged nuclei may be identified either mechanically as high-stress concentration[5] around blocked slip planes (textural stresses) or, physically, as accumulations of dislocations. Strain aging may, however, represent an alternative explanation of this effect since both the rates of relaxation and of strain aging are highly temperature sensitive, being governed in the form of "rate processes" by the activation energy of the material permanently strained in fatigue, which itself changes with the extent of permanent deformation. It appears reasonable to assume that the effect of rest periods will be intensified by elevated temperatures, though the character of the effect may not remain uniform and depend on the temperature level, as well as on the extent of prior slip and hardening produced during the fatigue loading.

The above results clearly show the effect of the number of rest periods as well as of their temperature and duration: for St. 37 an increase of the number of rest periods from 4–5 to 72–88 more than doubles the number of cycles to failure; for St60 an increase of the temperature of the rest periods from room temperature at 140° C or an increase of its duration from 1 min to 3 days increases the number of cycles to failure by, respectively, 200 and 170%.

Similar rotating beam fatigue tests performed at stress levels above the endurance limit on two low-carbon steels of different aging characteristics with a yield stress of 34,000 psi for the aging, and of 45,000 psi for the nonaging steel[2] also indicated a beneficial effect of intermittent rest periods as well as of one single rest period, particularly when during these rest periods the specimens were kept at an elevated temperature of 140° C. With an average uninterrupted life at a reversed stress of ±36,500 psi (endurance limit 31,000 psi) of 0.4×10^6 cycles, the introduction of one-day rest periods at intervals of $^1/_{10}$ of the average uninterrupted life increased the life by about 20% for rest periods at room temperature, and by about 70% for rest periods in oil at 140° C; one single rest period of 17 hr at 140° C increased the average life by about 45%.

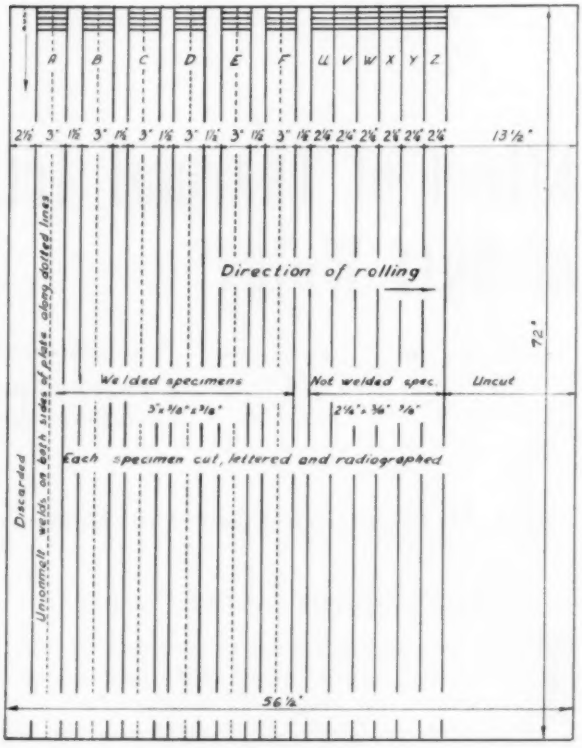


Fig. 1 Welded plate out of which fatigue specimens were cut

The introduction of intermittent elevated temperature rest periods of 17 hr duration at similar intervals in tests under a reversed bending stress of ±42,000 psi increased the average uninterrupted life of 0.1×10^6 cycles by more than sixfold to 0.62×10^6 cycles. Shortening of the duration of the rest period to 3 hr reduced the increase to about 60 to 100%.

Significant effects of rest periods were also obtained in repeated bending impact tests on medium carbon steel.[3] The rest periods were of 12 hr, 1, 3 and 7 days' duration, and were applied in intervals of about one-fifth of the number of impact loads sustained in non-interrupted tests. Intermittent rest periods had a beneficial effect only in tests run at 25 impact loadings per revolution, while no appreciable effect could be observed in tests run at 2 impact loadings per revolution. In the first case the increase in the number of impact loads sustained to fracture was insignificant for

Table 1—Tests by Daeves, Gerald and Schulz on Effect of Rest Periods[1]

Steel type	*No. of spec.*	*Stress 10^3, psi*	*No. of consecutive cycles in 10^3*	*Rest period*	*Life in 10^3*	*Increase (mean), %*
St.37	6	42	Uninterrupted	None	69–200	..
37	4	42	40	5 min at 140° C	175–211	57
37	6	42	20	5 min at 140° C	172–293	90
37	6	42	5	5 min at 140° C	362–441	227
St.60	6	55	Uninterrupted	None	93–155	..
60	6	55	10	3 days at room temperature	103–194	7
60	5	55	10	3 days at 140° C	314–410	226
60	4	55	10	5 min at 140° C	146–205	37
60	4	55	10	1 min at 140° C	132–161	21

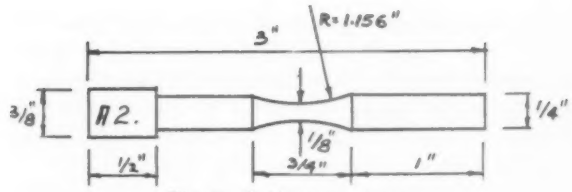


Fig. 2 Fatigue specimen

12-hr rest periods, but attained about 45% for 1-day periods, 63% for 3-day periods and 45% for 7-day periods.

In reversed axial load fatigue tests of cold-worked steel interrupted for short periods after 10^3, 10^4, 10^5, 10^6, etc., cycles H. J. Gough and W. A. Wood[4] reported a slight increase of the fatigue life in comparison to the results of uninterrupted tests. Since this effect was not related to the object of their research, no attempt was made at a quantitative evaluation of the reported observations.

Intermittently interrupted pulsating axial tension fatigue tests on various metals and alloys[5] (aluminum and magnesium alloys, brass) with rest periods ranging between 6 and 48 hr after every 10% of the expected minimum life did not show a noticeable effect on fatigue life. The life in the interrupted tests was usually within the scatter of the uninterrupted tests. A slight reduction of the life was found for a hardened aluminum alloy. The only exception was an extremely low-carbon steel. Under pulsating stresses slightly above the endurance limit the specimens showed considerable elongation and necking before fracture in an uninterrupted fatigue test. When the tests were interrupted for 23 hr at periods of about one-seventh of the expected fatigue life in the uninterrupted test, neither necking nor fracture occurred after 100 times as many cycles. This apparent increase of the endurance limit seems to be a distinct aging effect.

Rest periods at elevated temperatures were also found to have a considerable effect on damping in steel.[6] It is reported that the initial logarithmic decrement of $\delta = 2.1 \times 10^{-4}$ was increased to $\delta = 8.5 \times 10^{-4}$ by the application of 0.02×10^6 cycles at $\pm 42{,}000$ psi; in the subsequent 17-hr rest period at 140° C the decrement was reduced to a value slightly below the initial value; at a temperature below 100° C, however, the reduction was relatively small.

While the German investigations of the effect of rest periods was apparently interrupted by the war, an investigation was carried out in this country by the Committee of Fatigue Testing of the Welding Research Committee[7] on the effect of rest periods on the fatigue strength of butt-welded joints in relatively large specimens made out of $^1/_2$-in plate of a steel slightly softer than ASTM A-7 steel. The fatigue life of specimens was compared under conditions of continuous testing, 5 min rest periods after every 100 cycles and 30 min rest periods after 100 cycles. The scatter of the results in conjunction with the small number of test repetitions at each stress level makes a rational interpretation of the results practically impossible. The Committee interpreted the test results to indicate that rest periods have no significant effect. This statement, in the light of the scatter of the test results can only mean that the magnitude of possible effects of rest periods was certainly below the scatter range of these results; as this range was considerable, no conclusion can actually be drawn from the results.

The existence of recovery effects during fatigue tests at room temperature has been inferred from the observations in the cause of X-ray diffraction studies of a distinct sharpening of the Debeye-Scherrer lines in the later stages of fatigue tests, after they had been broadened in the early stages of the test as a result of crystal fragmentation. In fatigue tests on work-hardened

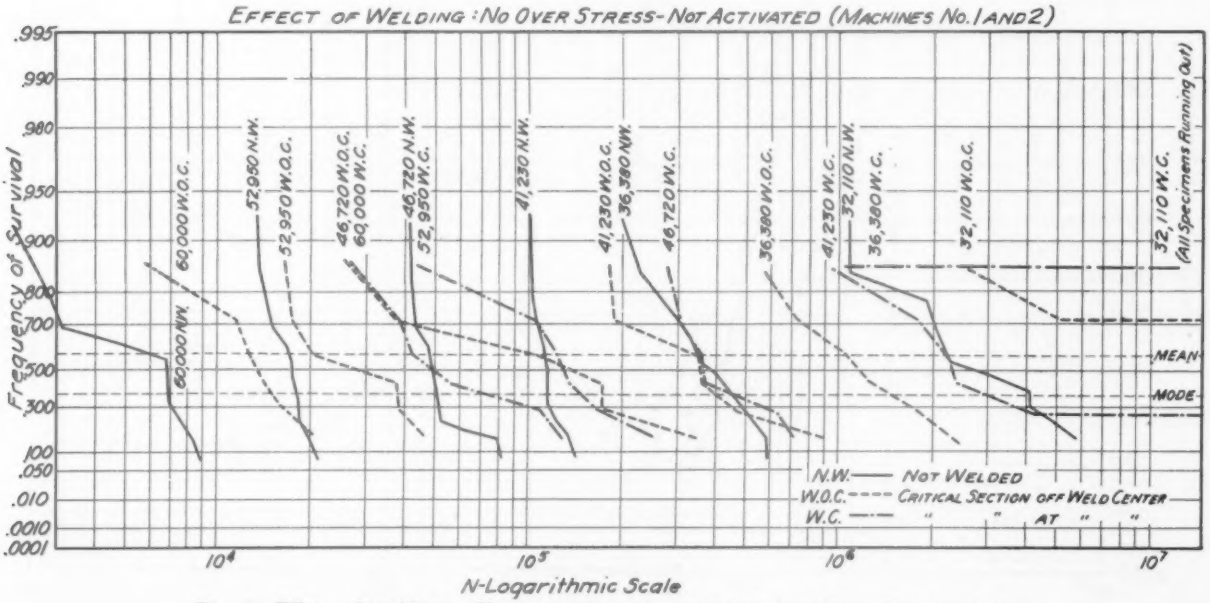


Fig. 3 Effect of welding: No overstress, not activated (machines Nos. 1 and 2)

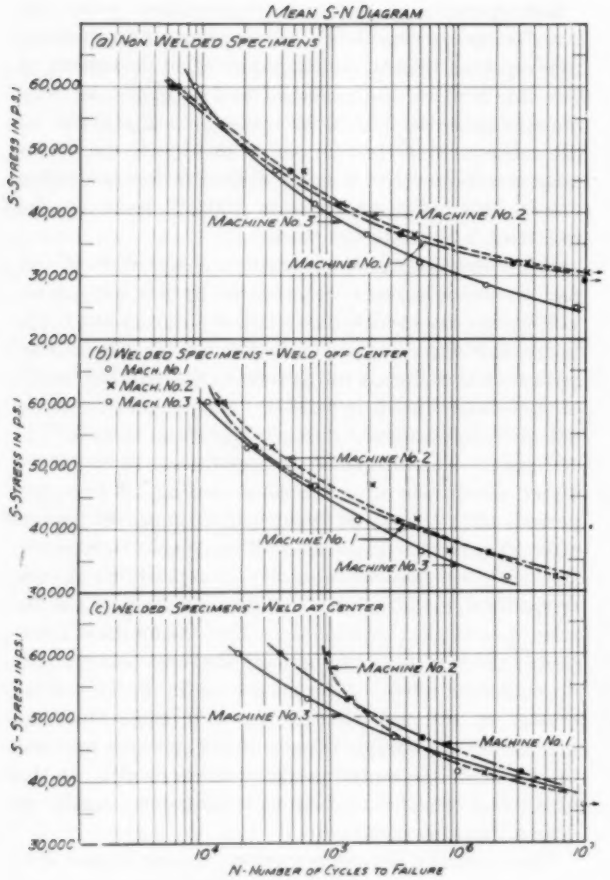

Mean S-N Diagram
(a) Non Welded Specimens
(b) Welded Specimens - Weld off Center
(c) Welded Specimens - Weld at Center
S-Stress in p.s.i.
N-Number of Cycles to Failure
Machine No. 1
Machine No. 2
Machine No. 3

Fig. 4 Mean S–N diagram

copper even definite signs of recrystallization were observed after about 0.5–0.75 × 10^6 load cycles;[8] a recrystallized ring around the perimeter of a highly stressed 0.081-in. diam copper wire could be made visible by etching.[9] Observations of similar effects on specimens of silver, copper and steel have been reported.[10–15]

A rather extensive investigation along the lines of the German pilot tests on rotating beam specimens was carried out under ONR sponsorship at the University of Illinois.[16] Small rotating beam specimens of two types of steel, SAE-4340 heat treated to about 165,000 psi tensile strength and SAE-1045, and high-purity electrolytic copper were used in this investigation. Before testing, all specimens were heated for about 2 hr in an oil bath at 350° F (steel) and 280° F (copper), respectively; for comparison a small number of tests were performed on specimens that had not been heated before the test, but no significant difference between the test results in the two groups could be observed.

The fatigue life of the specimens was observed in (*a*) uninterrupted tests, (*b*) in tests with intermittent 15–20 min rest periods at 350° F for steel and 280° F for copper applied at intervals of about one-tenth of the average fatigue life in uninterrupted tests and (*c*) in tests interrupted by a longer rest period ($^1/_2$–2 hr) at elevated temperature, once after an initial period of overstressing during which a substantial part of the total life had been expended, and then continued to failure at the (lower) test stress. The number of tests under

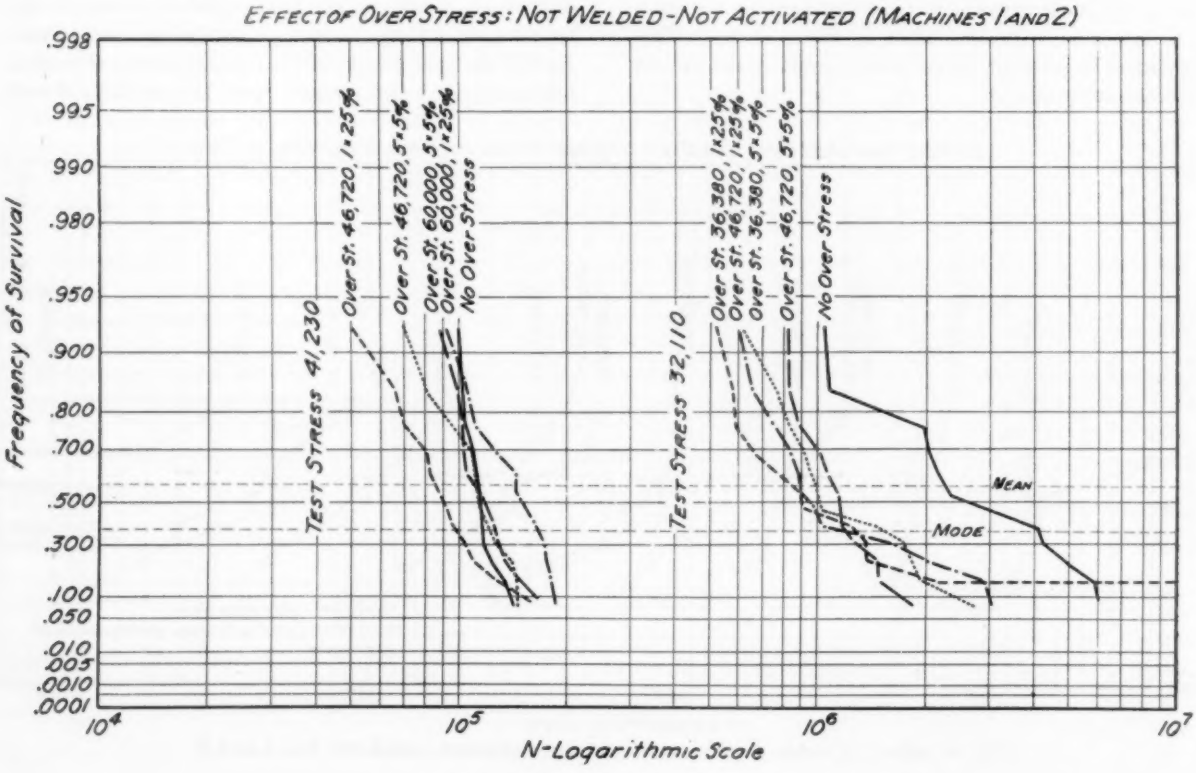


Fig. 5 *Effect of overstress: Not welded, not activated (machines Nos. 1 and 2)*

each condition were sufficiently large (10 to 27) to permit statistical evaluation of the data.

The test results show that for SAE-4340 steel the average fatigue life observed in uninterrupted tests is increased by intermittent, relatively short, rest periods at 350° F by about 50% (from 182 × 10^3 cycles to 275 × 10^3 cycles) for a stress of ±105,000 psi, and by about 33% (from 79 × 10^3 cycles to 108 × 10^3 cycles) for a stress of ±118,000 psi. The beneficial effect of intermittent rest periods was less pronounced for SAE-1045 steel, where the increase in fatigue life due to short rest periods did not exceed 15% of the average life in uninterrupted tests. When the number of rest periods was reduced, but their duration increased from 20 to 80 min, the average fatigue life was lengthened by 25% of the average uninterrupted life. A particularly marked increase of the average fatigue life of SAE-1045 from 110 × 10^3 cycles to 161 × 10^3 cycles was obtained when a 2-hr, elevated temperature rest period was applied immediately following an overstress period, before the specimens were tested to fracture at the (lower) test stress.

It should be noted that the majority of tests of SAE-1045 specimens were performed at reversed bending stresses above the static yield stress in tension, while all tests of SAE-4340 specimens were performed at stresses below the yield stress. It appears, however, that the extent of the effect of rest periods on the fatigue life of SAE-1045 steel was not significantly influenced by the stress level.

While the fatigue life of the steel specimens was lengthened by rest periods at elevated temperature, the result of the tests of the copper specimens show a marked trend in the opposite direction, particularly if the rest period follows a period of overstress. One 30-min rest period at 280° F or one 24-hr rest period at room temperature produced a 25% reduction of the average fatigue life. This difference between the behavior of steel and of copper suggests that rest at the applied combination of time and temperature, particularly after overstress, produced such thermal softening of the copper that it made it more susceptible to fatigue damage under the subsequent test stress and thus reduced its fatigue life under this stress. A similar, though less pronounced, thermal softening effect may also account for the difference in the effect of rest periods on SAE-4340 and SAE-1045.

PREPARATION OF SPECIMENS AND TESTING PROCEDURE

In the present tests small rotating beam specimens of ASTM A-285 steel with a butt weld at the critical section were used. The specimens were machined from $^3/_8$ by $^3/_8$ by 3-in. bars that had been cut from a large $^3/_8$-in. plate. This plate (56.6 x 72 in.) which was supplied by the Chicago Bridge and Iron Co. through the courtesy of Dr. Boardman was welded normal to the direction of the rolling along six parallel lines $4^1/_2$ in. apart, by the Unionmelt process (Fig. 1). The weld reinforcement was machined off and the welds were radiographed. The plate was first cut into strips 3.0 in. wide parallel to the weld direction $1^1/_2$ in. each side of the weld-center lines; these strips were then cut per-

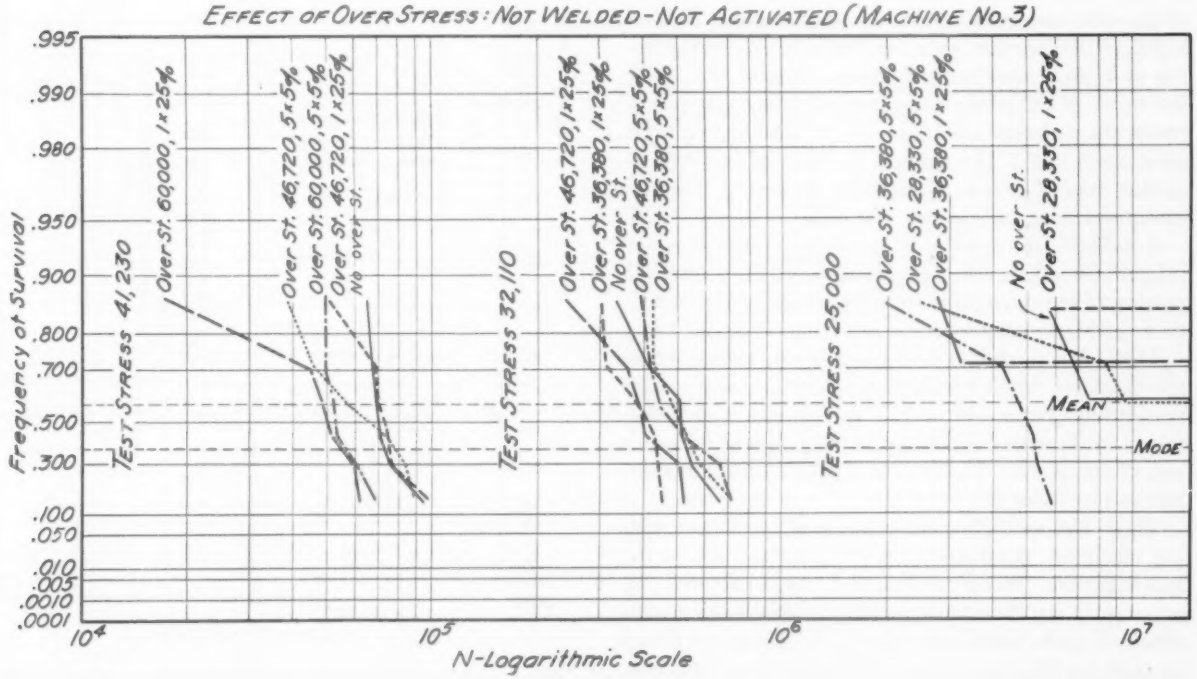


Fig. 6

pendicular to the welds into bars $^3/_8$ in. wide and 3 in. long which were numbered and out of which the specimens were subsequently machined. The radiograph of each weld was carefully considered and compared with the location of the individual specimens along the welds in an attempt to eliminate all specimens containing welds with real or apparent flaws.

The fact that the Unionmelt process was applied to the uncut plate makes the significance of the test results for conventional butt welds somewhat problematic. It was, however, the considered opinion of the members of the University Research Committee who were requested to express their opinion on this point, that differences in the fatigue performance of the Unionmelt welds and regular butt welds, if existing at all, would be insignificant, particularly since the properties of the heat-affected zones, the fatigue performance of which would presumably be more critical than that of the weld metal, would not be different.

The square bars were machined into 2-in. long specimens with a reduced section of 0.125 in., as shown in Fig. 2. They were given a standard fatigue finish by polishing with three successively finer grades of emery paper. The final polishing with No. 00 grade emery paper was parallel to the axis of the specimen.

Because of the expected difference of fatigue performance of the weld metal and the weld-affected zone it was decided to machine the specimens in two groups: one in which the critical section was located at the weld center, the other in which the critical section was located in the weld-affected zone. In order to determine the location of the critical section with respect to the weld, the weld location and width were established in a number of representative square bars from along each weld line in the plate. In those bars the cross section of the weld was made visible by polishing and etching and the distances were measured between one end of the bar and the centerline and outer edges of the weld; the width of the welds varied from 0.24 to 0.42 in. between the different lines, but was reasonably uniform along each line. The average location of the critical section was therefore established separately for the specimens along each of the weld lines.

A sufficiently large number of the same type of fatigue specimens were prepared from the unwelded portion of the same plate from which the welded specimens had been machined.

The elastic modulus, yield-point stress, ultimate tensile strength, percent reduction of area at failure and percent elongation over a 2-in. gage length were determined by 3 conventional tension tests on specimens cut out of the plate. The results of these tests are summarized in Table 2.

Three Krouse high-speed rotating beam fatigue testing machines, numbered 1, 2 and 3, were used in the investigation. Since preliminary tests showed an apparently significant discrepancy between the results obtained under assumedly identical testing conditions on machine No. 3 and those obtained on machines Nos. 1 and 2, a statistical study was made of the differences

Table 2—Results of Static Tension Tests

	Specimen		
	No. 1	*No. 2*	*No. 3*
Yield point stress, psi	31,262	34,093	37,178
Nominal ultimate stress, psi	53,901	52,688	54,972
True ultimate stress, psi	126,750	125,444	124,800
Percent reduction of area, %	71.04	69.53	72.58
Percent elongation in 2 in., %	25.25	30.00	25.00
Modulus of elasticity, psi	34.3	27.1	32.8

of the results obtained on each of the 3 machines. In spite of the fact that no difference could be found between the 3 machines which are of identical type and manufacture and had been purchased at the same time, the results of Machine 3 were found to belong to a statistical population different from that obtained in Machines 1 and 2, which were shown to belong to the same population and could therefore be combined.

This result interfered quite adversely with the testing program and procedure, particularly, with respect to its

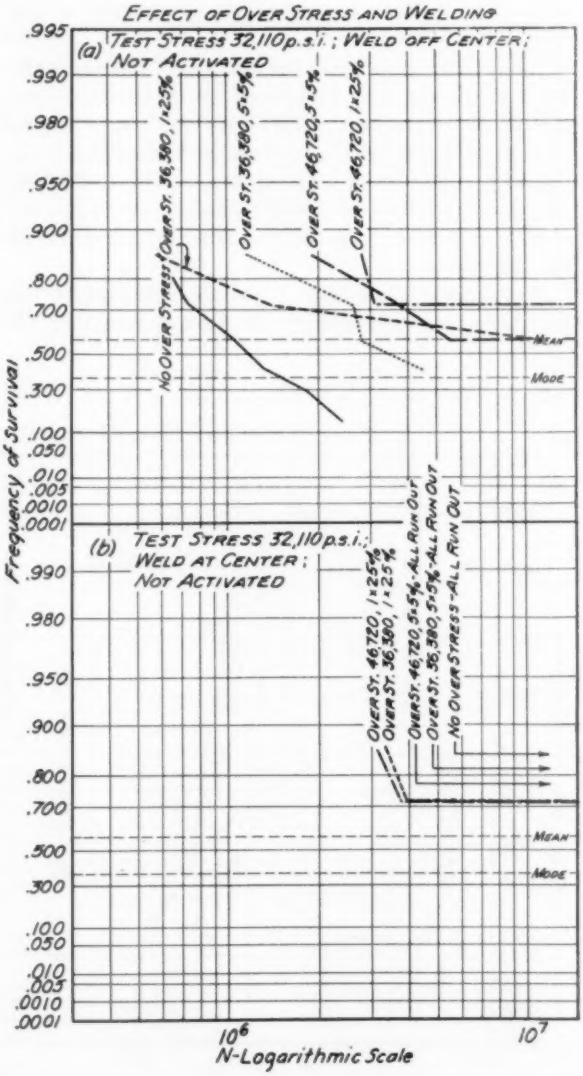


Fig. 7 Effect of overstress and welding (test stress, 32,110 psi)

planning for statistical evaluation. It had been intended to test 6 specimens on each machine under identical conditions, so as to have 18 repetitions of each result, which was considered an adequate number for statistical evaluation. With one machine giving consistently different results, a maximum of only 12 repetitions could be obtained. In certain cases even this number had to be halved, when it became evident that 2 parallel investigations were necessary, one for specimens with the critical section at the weld center, the other for specimens with the critical section in the weld-affected zone. Even so the total number of specimens tested was roughly 800.

The test results were statistically analyzed on the basis of a theory presented in a recent paper by one of the authors.[17] According to this theory the variation of the logarithm of the fatigue life can be represented by the statistical distribution of extreme (smallest) values; test results should therefore fall closely enough on a straight line if plotted on a specially developed logarithmic-extreme-value probability paper; all test results have been so presented. The plotting position P_m of each of the n test results, after having been arranged in ascending order, has been determined from the relation $P_m = 1 - [m/(n + 1)]$ where m is the order number of the individual result. The resulting diagrams are "survival functions" the ordinates of which indicate the probability of occurrence of values of the

Table 3—Number of Cycles to Failure (N in Hundreds); Nonwelded

Stress level, psi						
	Machine No. 1					
60,000	27	28	68	68	76	90
52,950	145	174	176	180	202	214
46,720	423	470	484	583	795	826
41,230	1,150	1,164	1,168	1,171	1,232	1,326
36,380	2,008	3,206	4,400	5,450	5,803	5,932
32,110	20,510	21,820	23,180	41,503	58,870	60,750
28,330	65,970	*	*	*	*	*
	Machine No. 2					
60,000	24	32	49	67	70	84
52,950	137	138	149	167	185	186
46,720	429	437	443	510	520	521
41,230	1,011	1,045	1,050	1,093	1,135	1,430
36,380	2,281	2,718	3,488	3,628	4,140	4,742
32,110	10,600	10,760	19,170	30,420	41,470	49,090
28,330	76,970	*	*	*	*	*
	Machine No. 4					
60,000	61	64	66	70	107	131
52,950	92	110	123	129	133	212
46,720	311	312	331	363	402	412
41,230	648	676	687	714	758	941
36,380	1,134	1,330	1,570	2,166	2,530	2672
32,110	3,348	4,054	5,045	5,115	5,670	6531
28,330	9,965	16,437	16,527	16,983	23,631	*
25,000	58,252	69,913	75,720	*	*	*

* $>10 \times 10^6$ cycles.

Table 4—Number of Cycles to Failure (N in Hundreds); Welded

Stress level, psi						
	Machine No. 1					
	Weld at center			*Weld off-center*		
60,000	278	386	556	57	129	204
52,950	1,218	1,330	1631	168	293	387
46,720	3,592	6,211	7086	268	380	1,706
41,230	23,418	42,217	*	1,884	3,649	4,768
36,380	*	*	*	10,630	18,158	24,509
32,110	*	*	*	*	*	*
28,330	*	*	*	*	*	*
	Machine No. 2					
60,000	429	1,082	1,290	115	145	165
52,950	450	1,058	2,563	172	392	457
46,720	2,834	3,091	3,696	1,094	1,707	3,559
41,230	9,298	17,781	22,627	1,824	3,570	9,049
36,380	10,382	*	*	5,812	7,458	12,789
32,110	*	*	*	25,442	52,009	*
28,330	*	*	*	*	*	*
	Machine No. 3					
60,000	120	184	266	87	87	152
52,950	483	714	835	188	231	240
46,720	1956	2113	12,859	384	838	1,052
41,230	7390	7490	15,517	1374	1,569	2,053
36,380	*	*	*	5114	5,409	*
32,110	*	*	*	5927	20,395	48,807
28,330	*	*	*	*	*	*
25,000	*	*	*	*	*	*

* $>10 \times 10^6$ cycles.

fatigue life longer than the value of the abscissa pertaining to this probability.

The following testing program was adopted:

The mean S–N diagram was determined by testing 6 specimens in each machine at 8 logarithmically equally spaced stress levels enclosed between a reversed stress level of ±25,000 psi, which is somewhat above the endurance limit, and a nominal stress level of ±60,000 psi. Each stress level is 13.3% higher than the preceding one. The following are the stress-levels applied:

σ_1 = 25,000 psi	σ_5 = 41,230 psi
σ_2 = 28,330 psi	σ_6 = 46,720 psi
σ_3 = 32,110 psi	σ_7 = 52,950 psi
σ_4 = 36,380 psi	σ_8 = 60,000 psi

Table 5—Number of Cycles to Failure (N in Hundreds); Nonwelded, Overstressed

Test stress, psi	*Over-stress, psi*	*Amount of overstress, %*	*Test No.*						
				Machine No. 1					
41,230	46,720	5 × 5	1	1,110	1,216	1,263	1,402	1,440	1,455
		1 × 25	2	882	933	956	1,040	1,285	1,635
	60,000	5 × 5	3	1,042	1,267	1,288	1,344	1,492	1,732
		1 × 25	4	1,290	1,664	1,752	1,762	1,812	1,897
32,110	36,380	5 × 5	5	10,129	14,556	17,274	18,438	18,942	26,960
		1 × 25	6	7,883	9,029	12,410	13,626	21,593	*
	46,720	5 × 5	7	10,876	11,598	12,641	14,605	14,867	18,406
		1 × 25	8	6,101	9,994	10,324	15,750	20,079	28,279
				Machine No. 2					
41,230	46,720	5 × 5	1	713	826	978	1,113	1,120	1,140
		1 × 25	2	512	660	703	832	842	1,111
	60,000	5 × 5	3	890	991	1030	1,045	1,190	1,210
		1 × 25	4	939	1060	1122	1,467	1,477	1,531
32,110	36,380	5 × 5	5	6258	7631	8399	9,349	9,591	11,133
		1 × 25	6	5338	5802	5949	6,601	9,239	13,759
	46,720	5 × 5	7	8379	8401	8948	10,165	11,445	11,612
		1 × 25	8	6560	7601	8446	8,905	9,008	30,966
				Machine No. 3					
41,230	46,720	5 × 5	1	527	692	713	766	771	991
		1 × 25	2	396	460	579	747	841	885
	60,000	5 × 5	3	502	502	529	548	611	624
		1 × 25	4	174	442	483	522	615	692
32,110	36,380	5 × 5	5	4,302	4,327	4,811	4,955	5,339	7,206
		1 × 25	6	3,046	3,177	3,911	4,052	5,156	5,263
	46,720	5 × 5	7	4,059	4,246	4,561	5,276	6,655	7,176
		1 × 25	8	2,498	3,575	3,907	4,328	4,443	4,531
25,000	28,330	5 × 5	9	25,746	83,984	95,902	*	*	*
		1 × 25	10	59,264	*	*	*	*	*
	36,380	5 × 5	11	20,685	42,817	47,972	52,885	54,452	58,596
		1 × 25	12	27,859	32,705	*	*	*	*

* >10 × 10^6 cycles.

Table 6—Number of Cycles to Failure (N in Hundreds); Welded, Overstressed

Test stress, psi	*Over-stress, psi*	*Amount of overstress %*	*Test No.*						
				Machine No. 1					
				Weld at Center			*Weld Off-center*		
41,230	46,720	5 × 5	1	24,265	25,420	31,501	5,656	6,239	18,008
		1 × 25	2	12,856	12,857	18,006	4,759	7,523	12,316
	60,000	5 × 5	3	13,439	14,488	20,069	3,660	4,392	4,933
		1 × 25	4	9,516	11,974	12,458	5,303	8,091	71,992
32,110	36,380	5 × 5	5	*	*	*	11,841	25,890	*
		1 × 25	6	*	*	*	5,798	97,842	*
	46,720	5 × 5	7	*	*	*	19,150	55,753	*
		1 × 25	8	31,234	37,791	*	*	*	*
				Machine No. 2					
41,230	46,720	5 × 5	1	13,650	19,386	21,608	3,187	6,282	*
		1 × 25	2	6,480	10,729	16,572	8,321	15,752	25,781
	60,000	5 × 5	3	2,667	6,043	9,056	3,738	6,690	12,524
		1 × 25	4	2,651	2,690	2,754	7,605	8,505	*
32,110	36,380	5 × 5	5	*	*	*	27,454	43,931	*
		1 × 25	6	34,207	38,126	*	14,009	*	*
	46,720	5 × 5	7	*	*	*	37,601	*	*
		1 × 25	8	*	*	*	27,698	31,126	*
				Machine No. 3					
41,230	46,720	5 × 5	1	5,224	5,591	6,947	667	1,192	2,171
		1 × 25	2	4,362	5,882	6,262	2,515	2,788	4,720
	60,000	5 × 5	3	3,710	4,223	6,766	3,345	4,047	4,762
		1 × 25	4	1,698	4,926	5,002	871	1,289	2,098
32,110	36,380	5 × 5	5	37,904	59,785	70,671	38,877	*	*
		1 × 25	6	22,704	34,361	63,232	5,760	6,689	13,388
	46,720	5 × 5	7	16,678	34,375	*	18,200	28,879	*
		1 × 25	8	15,986	16,064	16,879	6,808	33,249	*

* >10 × 10^6 cycles.

It is evident that all stress levels above σ_s are presumably above the yield-point stress in bending and can therefore only be considered as nominal, since the stress distributions will no longer be elastic.

The stress levels of ±25,000, ±32,110 and 41,230 psi were selected as test stresses. Two overstress levels ("low" and "high") were chosen for each test stress: the "low" level is one interval, the "high" level three intervals above the test stress. Thus the overstress levels for the 3 test stresses are ±28,330, and ±36,380 psi, ±36,380 and ±46,720 psi, ±46,720 and ±60,000 psi, respectively.

In order to establish the mean S–N diagrams the nonwelded specimens were tested at all eight stress levels and their mean fatigue life was determined. Six specimens were tested on each machine at each stress level. The same was done with the two groups of welded specimen, one with the weld center at the reduced section, the other with the weld edge at the reduced section. Three of each at each level were tested on each machine.

In the subsequent overstress tests the specimens were subjected to various sequences of overstressing. The overstress was applied in two different sequences:

(*a*) Specimens were run to 15% of the mean fatigue life at the test stress, followed by 5% of the mean life at the particular overstress selected; this sequence was repeated five times after which, provided the specimen had not failed, it was subjected to the test stress until fracture or run-out (defined as $>10 \times 10^6$ cycles).

(*b*) Specimens were run to 15% of life at test stress followed by 25% of life at the selected overstress; the test then continued at the test stress until fracture or run-out.

The same overstressing procedure was repeated with thermal activation following every overstress period. After a specimen had been subjected to the overstress cycles it was removed from the machine and submerged in a Dow-Corning silicon fluid for 36 min at 480° F for the short overstress sequence (5%) and for 3 hr after the long (25%) overstress sequence.

TEST RESULTS

The test results are presented in Tables 3 to 7; they have been plotted on extreme value probability paper in Figs. 3 to 11 for a graphical illustration of the following effects:

(*a*) effect of welding on not-overstressed, not-activated specimens (Figs. 3 and 4).

(*b*) effect of overstress on not-welded, not-activated specimens (Figs. 5 and 6).

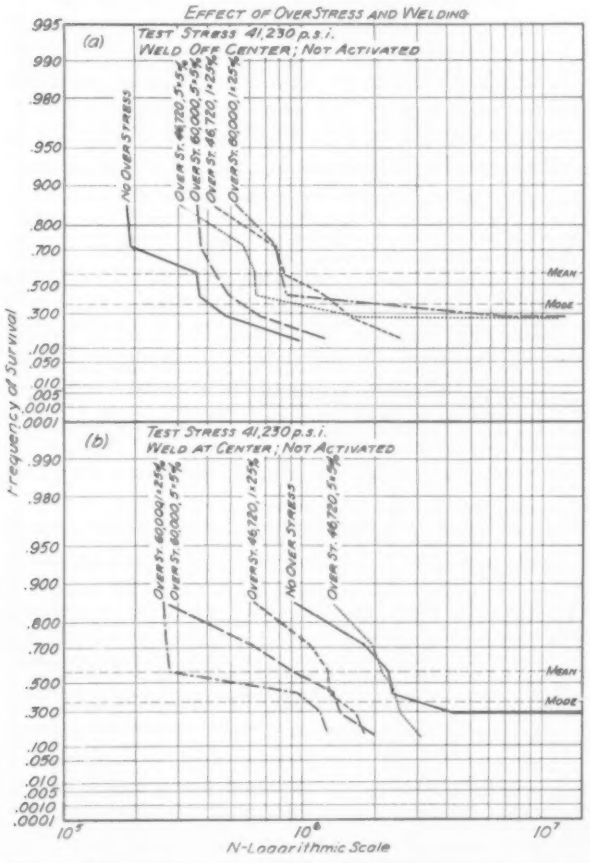


Fig. 8 Effect of overstress and welding (test stress, 41,230 psi

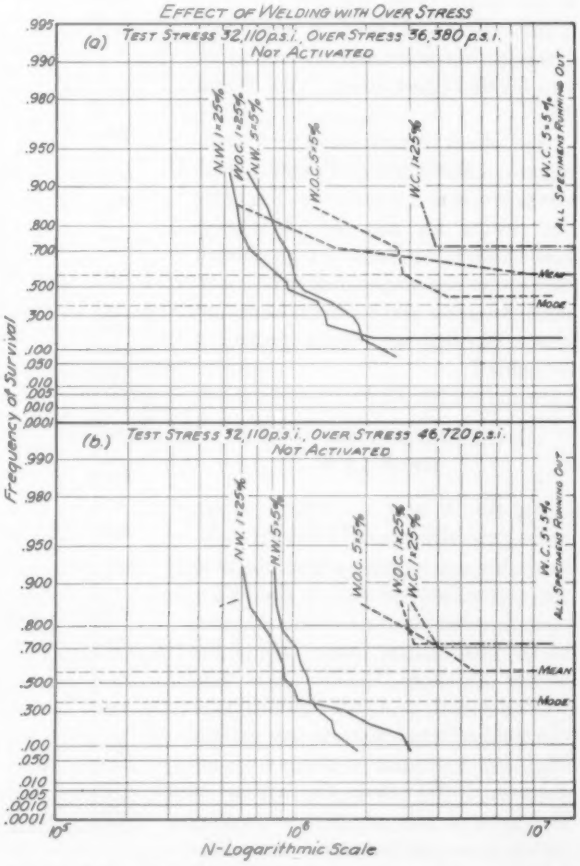


Fig. 9 Effect of welding with overstress (test stress, 32,110 psi)

Table 7—Number of Cycles to Failure (N in Hundreds); Welded Activated

Test stress, psi	Over-stress, psi	Amount of overstress, %	Test No.	Weld at Center			Weld Off-center		
				Machine No. 1					
41,230	46,720	5 × 5	13	7,861	21,318	26,425	1,405	4,661	*
		1 × 25	14	14,415	16,337		2,789	2,831	4,697
	60,000	5 × 5	15	11,403	12,189	14,100	7,497	8,838	17,239
		1 × 25	16	5,018	8,962	9,136	3,564	4,561	4,651
32,110	36,380	5 × 5	17	*	*	*	63,928	*	*
		1 × 25	18	*	*	*	*	*	*
	46,720	5 × 5	19	*	*	*	76,645	*	*
		1 × 25	20	32,820	*	*	*	*	*
				Machine No. 2					
41,230	46,720	5 × 5	13	17,343	23,457	26,754	1,536	2,213	3,302
		1 × 25	14	30,331	44,090		1,280	1,913	10,767
	60,000	5 × 5	15	7,593	7,635	9,594	3,629	7,078	14,107
		1 × 25	16	3,727	3,941	4,827	3,058	3,397	8,949
32,110	36,380	5 × 5	17	38,011	*	*	*	*	*
		1 × 25	18	44,513	*	*	44,513 ⌐	*	*
	46,720	5 × 5	19	*	*	*	*	*	*
		1 × 25	20	*	*	*	32,981 ⌐	52,656 ⌐	*
				Machine No. 3					
41,230	46,720	5 × 5	13	4,763	5,042	5,971	2,372	2,958	5,253
		1 × 25	14	4,184	4,776	8,599	371	1,233	2,032
	60,000	5 × 5	15	3,070	3,838	6,134	3,323	7,796	8,413
		1 × 25	16	3,276	3,839	4,757	3,865	4,497	6,930
32,110	36,380	5 × 5	17	28,287	42,770	*	11,030	*	*
		1 × 25	18	35,363	52,515	*	52,032	52,346	91,570
	46,720	5 × 5	19	48,401	56,717	68,469	72,608	*	*
		1 × 25	20	16,620	16,910	19,447	5,334	11,129	15,936

* $>10 \times 10^8$ cycles.

(*c*) effect of overstress on welded, not-activated specimens at two levels of test stress (Figs. 7 and 8).

(*d*) effect of welding on overstressed, not-activated specimens at two levels of test stress (Figs. 9 and 10).

(*e*) effect of activation and welding at one test stress and various overstress levels and sequences (Fig. 11); the results for the second (lower) test-stress level could not be plotted because of the large number of specimens running out; conclusions are based directly on results presented in Table 7.

DISCUSSION OF TEST RESULTS

Figures 3 and 4 indicate that, quite generally, the butt-welded specimens have a longer fatigue life than the nonwelded specimens, the difference is considerable for the material at the weld center (mean fatigue life about 10 times that of the nonwelded metal) and still significant for the weld-affected zone (mean fatigue life about twice that of the nonwelded material). However, the scatter of the fatigue life of the nonwelded metal is much narrower than that of the weld metal and the weld-affected zone. Only for the non-

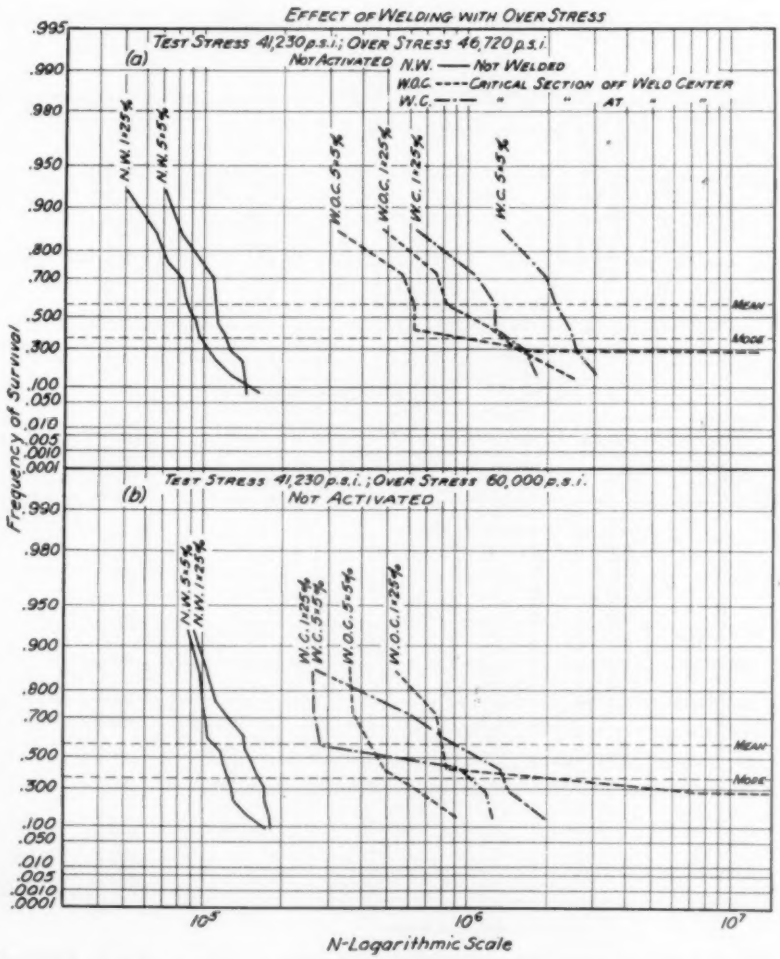


Fig. 10 Effect of welding with overstress (test stress, 41,230 psi)

welded metal is an increase of scatter with decreasing stress level clearly noticeable; the scatter for the weld metals and weld-affected zone is apparently not affected by the stress level, probably because the welding process introduces considerable scatter even at the high stress levels at which the scatter of the fatigue life of the nonwelded metal is quite narrow.

Figure 4 illustrates the machine effect and shows the necessity to identify the different testing machines both in the planning of the tests and in the analysis of the test results. The "mean life" used for the specification of the number of overstress cycles is different for different machines. The test results obtained on machines Nos. 1 and 2 have been combined on the basis of the result of a statistical analysis of the significance of the differences in the means and the variances obtained on the three machines. A careful check of all assumedly significant machine characteristics failed to disclose any difference that could have accounted for the considerably shorter lives observed on machine No. 3.

Figures 5 and 6 shows for the unwelded metal that if both the nominal test stress and the overstress levels are beyond the yield stress no clear damage effect due to overstress is observable; on the contrary, a mild overstress appears even to increase the fatigue life somewhat. Only if at least the test stress is below the yield stress, damage due to overstress becomes noticeable, though neither overstress level nor overstress sequence seem to affect the fatigue damage significantly; thus it appears that the damage due to a nominal overstress exceeding the yield stress does not depend on the level of such overstress, that is, on the depth of penetration of the plastic zone. The scatter of the test results appears to increase with decreasing test stress level. No effect of overstress sequence could be observed.

Figures 7 and 8 suggest that for the weld metal overstress reduces the fatigue life, while a similar overstress increases the life of the metal in the weld-affected zone. With respect to the life increase the overstress sequence appears to be of no influence, while the life shortening seems more pronounced when the overstress is applied in one block of 25% of the mean life rather than in 5 blocks of 5% each. The lengthening of the life by overstress of the weld-affected metal seems to be the more significant the higher the nominal overstress level.

Figures 9 and 10 again illustrate the general lengthening of fatigue life as a result of welding, in this case for specimens subjected to overstress. This lengthening of fatigue life is quite pronounced for both the weld metal and the weld-affected zone. No consistent influence of overstress sequence was noticeable.

The effect of thermal activation, as indicated in Fig. 11 and Table 7, appears to be rather erratic. For the nominal test-stress and overstress levels above the yield stress, thermal activation has apparently reduced the fatigue life of the metal in the weld-affected zone, while it lengthened, in general, the fatigue life of the weld metal. For a test stress within the elastic range, but overstresses above the yield point, thermal activation seemed to produce a beneficial effect as shown in

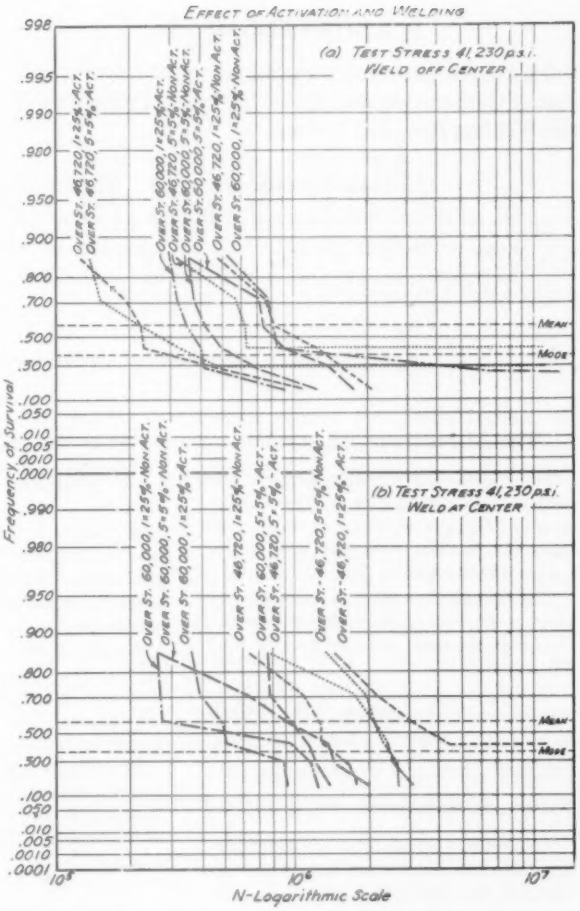


Fig. 11 Effect of activation and welding

the increase of the number of run-out specimens in the test series with thermal activation following overstress. Under this test stress the beneficial effect of activation appears to be more pronounced in the weld-affected zone than in the weld metal.

The few tests at the stress level of 25,000 psi cannot be analyzed since all welded specimens ran out at this level.

CONCLUSIONS

In spite of the large number of specimens tested very few definite conclusions can be drawn from the test results.

It appears that for mild steel the Unionmelt process produces butt welds of longer mean fatigue life than that of the nonwelded metal. Probably because of such effect of the welding process, thermal activation following overstress does not appear to be as significantly beneficial with respect to the fatigue life of butt welds as previous investigations on nonwelded specimens seemed to suggest. Such beneficial effect, where it could be observed, was limited to test stress levels below the yield point.

ACKNOWLEDGMENT

This investigation was supported jointly by the Research Corporation and by a University Fellowship of the Welding Research Council.

References

1. Daeves, K., Gerald, E., and Schulz, E. H., *Stahl u. Eisen*, **60**, 100 (1940).
2. Karius, A., Gerald, E., and Schulz, E. H., *Arch. Eisenhüttenw.*, **18**, 155 (1945).
3. Schulz, E. H., and Puengel, W., *Mitt. Versuchsanst. Deutsch-Luxemb. Berg u. Huetten A. G. Dortmund*, **1**, 43 (1922).
4. Gough, H. J., and Wood, W. A., *Proc. Roy. Soc. A.*, **165**, 358 (1938).
5. Bollenrath, F., and Cornelius, H., *VDI Zft.*, **84**, 295 (1940).
6. Oshiba, F., *Sci. Rep. Tohoku Imp. Univ.*, **28**, 370 (1940).
7. Wilson, W. M., and Wilder, A. B., THE WELDING JOURNAL, **19**, 100 (1940).
8. Dehlinger, U., *Metallwirtschaft*, **10**, 26 (1931).
9. Jackson, L. R., Battelle Memorial Institute (private communication).
10. Pfarr, B., *Z. tech. Phys.*, **14**, 220 (1933).
11. Pomp, A., and Zapp, B., *Mitt. Kaiser-Wilhelm-Inst. Eisenforsch.*, **15**, 21 (1933).
12. Koerber, F., and Hempel, M., *Ibid.*, **17**, 255 (1935).
13. Martin, E., *Arch. Eisenhüttenw.*, **10**, 415 (1937).
14. Dorgelo, H. B., and Neeteson, P. A., *De Ingenieur*, **51**, 221 (1936).
15. Dance, J. B., Council of Scient. and Ind. Res. in Australia, Div. of Aeron., 1946.
16. Freudenthal, A. M., Yen, C. S., and Sinclair, G. M., Eighth Progress Report, Contract N6-ori-71, IV, NR-031-005, 1948.
17. Freudenthal, A. M., and Gumbel, E. J., *Proc. Royal Soc. A.* **218**, 309 (1953).

The Microscopy of Metals

The Institution of Metallurgists announces the availability of *The Microscopy of Metals*, a publication which contains the lectures delivered at the Refresher Course held in 1953.

The contributors are well known as experts in the fields of knowledge with which their lectures deal and the book is fully illustrated.

Copies are obtainable from the Registrar-Secretary, Institution of Metallurgists, 28 Victoria St., London, S. W. 1. Priced 15/6*d*.

Armour Research Foundation

A colorful, 14-page brochure summarizing facilities available for metals research has been published by Armour Research Foundation of Illinois Institute of Technology, Chicago.

The brochure describes the personnel, their experience, and the services offered by the metals research department's staff of 115 technicians, engineers, and scientists.

The publication outlines the facilities available in the fields of powder metallurgy, applied metallurgy, electrochemistry, extraction metallurgy, foundry and steelmaking, mechanical metallurgy, nonferrous metallurgy, physical metallurgy, metallography and welding.

A chart in the brochure illustrates how the "Armour Plan," a cooperative method of attacking research problems, works for the sponsor of a research project in the metals field.

Free copies may be obtained from the Metals Research Department, Armour Research Foundation of Illinois Institute of Technology, 3350 S. Federal St., Chicago 16.

Film on "The Resistance Welding of Stainless Steels"

The resistance Welder Manufacturers' Assn., 1900 Arch St., Philadelphia 3, Pa., has announced that they have recently added to their film library a copy of "The Resistance Welding of Stainless Steels," which is available for schools, universities and plants for scheduled showings.

This film, prepared by the Allegheny Ludlum Steel Corp., is of particular value to production people and designers, engineers and metallurgists, training courses and classes in technology, and records, step by step, the complete resistance welding operation.

It covers the various types of equipment used, the proper handling of stainless steels prior to welding, the different weld joints made, and the precautions to be observed if the excellent properties of stainless are to be present in the finished product.

"The Resistance Welding of Stainless Steels" is a 16-mm film, running for 21 min, and has both sound and color.

Requests for its use should be sent direct to Association Headquarters at 1900 Arch St., Philadelphia 3, Pa.

Bound Volumes Welding Research Supplement

An inventory of the bound volumes indicates that the Welding Research Council could spare a few bound volumes for certain years. The Council proposes to dispose of these volumes as long as they last at $15 per volume. Each volume is bound in imitation leather covers and contains an index. Each volume probably represents more than a million dollars worth of research. Volumes for the following years are still available: 1939, 1940, 1941, 1944, 1945, 1946, 1947, 1948, 1949, 1950, 1951, 1952 and 1953.

WELDABILITY OF STEELS

An outstanding summary of current knowledge of the Weldability of Carbon & Low Alloy Steels prepared by Drs. R. D. Stout and W. D'Orville Doty under the direction of the Weldability Committee of the Welding Research Council.

Book of 381 pages including tables for welding ASTM, SAE, ABS and other specification Steels in all thicknesses.

List Price $6.50. A 20% discount to members AWS. Limited Edition. Order your copy now!

AMERICAN WELDING SOCIETY
33 West 39th St.
New York 18, N. Y.

Study of the Cooling Rates in Flash Welds in Steel

Cooling rates of flash welds in steel as functions of clamping distance, material thickness and rate of platen acceleration using the parabolic flashing patterns

by E. F. Nippes, Warren F. Savage, Gordon Grotke and S. M. Robelotto

Abstract

Weld centerline rates of cooling at 1300, 1000 and 900° F were determined as functions of three welding variables, the rate of platen acceleration, the final clamping distance, and the thickness of the material, for flash welds employing parabolic flashing patterns. Three rates of platen acceleration, 0.120, 0.042 and 0.0166 ips,[2] were investigated, with a range of final clamping distances of 0.3 to 1.2 in., for rectangular bar material of 0.250 and 0.375 in. thickness.

Flash welding variables within these limits resulted in weld centerline cooling rates, at 1300° F, ranging from a minimum of 40° F/sec to a maximum of 365° F/sec. Increasing platen acceleration, increasing section thickness and decreasing final clamping distance resulted in an increased rate of cooling. In both alloy steels studied, AISI 4130 and 4340, the formation of considerable amounts of martensite at the weld line could not be avoided by any reasonable adjustment of flash welding variables studied.

Flash welds were prepared using AISI 1020, 4130 and 4340 steels at four predetermined rates of cooling. Photomicrographs and the results of hardness and tensile tests are presented and discussed to relate the weld properties and the weld-zone microstructures.

INTRODUCTION

THE production of a satisfactory flash weld involves the proper proportioning of several variables. In order to simplify the task of evaluating the contribution of each of the numerous variables, a systematic study of the flash welding of steel has been in process for several years at the Welding Laboratory at Rensselaer Polytechnic Institute. Work thus far completed and reported[1, 2] has dealt with studies of the contribution of the flashing variables to the temperature distribution at the instant of upset. This course of action resulted from the philosophy that the effect of upset variables could not be investigated intelligently until a thorough knowledge of the effect of the flashing variables had been acquired.

The results of the flashing studies[1, 2] led to the following conclusions:

1. A stable temperature distribution can be obtained with less material burn-off if a constant rate of platen acceleration is employed during flashing instead of the more widely used constant velocity of platen motion.

2. The stable temperature distribution obtained may be predicted from the flashing variables, platen acceleration, initial clamping distance and section thickness, using an empirically determined flashing parameter.

As a result of the fact that a stable temperature distribution may be obtained with less material burn-off where a constant rate of platen acceleration is employed, this type of flashing pattern, known as parabolic flashing, was employed throughout the present research. Since the stable temperature gradient, once established by parabolic flashing, remains unchanged over a wide range of flashing burn-off values, the point of initiation of upset could be changed without affecting the temperature distribution, thus simplifying the study of upset variables.

The ability to predict the stable temperature distribution from the values of the flashing variables employed permitted studying the effect of the temperature distribution at upset on the upsetting action and the cooling rate at the weld centerline. Thus, known temperature distributions could be established in different specimens and the effect of varying the temperature distribution on the upset studied.

This report summarizes the results of the studies of flashing and upset variables on the cooling rate at the weld centerline, and attempts to correlate the observed weld microstructures and properties with the metallurgical behavior of the steels used and the weld cooling rates. The first portion of the report deals exclusively

E. F. Nippes, Warren F. Savage, Gordon Grotke and S. M. Robelotto are with the Rensselaer Polytechnic Institute, Troy, N. Y.

Presented at the Thirty-Fourth National Fall Meeting, AWS, held in Cleveland, Ohio, Oct. 19–23, 1953.

with the techniques used and the results obtained in the cooling rate investigation. The second portion of the report summarizes the mechanical and metallurgical properties of welds made in AISI 1020, 4130 and 4340 steels, and draws heavily upon the results of the first portion in explaining the observed properties.

OBJECT AND SCOPE

The object of this investigation was threefold:

1. To determine the rates of cooling which are associated with the flash welding process and to evaluate the contribution of important flash welding variables to these cooling rates.
2. Employing alloy steels, to examine and test welds prepared at known rates of cooling in order to correlate the mechanical properties of the weld and the weld-zone microstructure.
3. To investigate the effect of the composition of the steel on the upset properties and upset force requirements for flash welding.

MATERIAL

Since the thermal and electrical properties of most constructional steels are not significantly altered by chemical composition,[3] all specimens employed for the determination of cooling rates were prepared from AISI 1020 steel. Specimen welds for metallographic studies and tensile tests were prepared using three steels of different hardenability. The steels used for this portion of the investigation are listed, together with their compositions, in Table 1.

All material was hot-rolled, and supplied in the pickled and oiled condition. The steels were degreased prior to use and excessive scale removed, where necessary, by abrasive-belt grinding. No special end preparation was utilized other than cutting to length on an abrasive cutting-off wheel, and removing the burr by a light grinding operation.

Two specimen sizes were employed in this investigation: (1) 0.250- x 2- x 6-in. rectangular specimens and (2) 0.375- x 2- x 6-in. rectangular specimens.

EQUIPMENT

Welding Equipment

This investigation was conducted using a Federal 300-kva flash welder modified in this laboratory as described in previous reports.[4, 5] Power supply for welding was obtained from a single-phase alternator driven by a synchronous motor as previously described.

Instrumentation

The data for this investigation were obtained using a Consolidated Engineering Corp. 18-channel recording oscillograph.

Part I

EFFECT OF WELDING VARIABLES ON COOLING RATES IN FLASH WELDS

Preparation of Specimens and Procedure for Obtaining Thermal Data

The experimental data for the cooling rate determinations were obtained using either 0.250- x 2- x 6-in. or 0.375- x 2- x 6-in. specimens of AISI 1020. One specimen of each pair to be welded was drilled with 0.052-in. diam holes for the insertion of seven thermocouples. The holes were located at 0.1-in. intervals by use of a specially constructed jig, previously described.[1] A fixed backing plate of heavy steel was bolted to the fixed platen of the flash welder to prevent the specimens from slipping in the clamping jaws. This required that the drilled specimens, which were mounted on the fixed platen, be cut to an exact length. The undrilled specimen was supported by an adjustable backing, and the length of this piece was not critical. Although considerable difficulty was experienced with slipping in the jaws prior to the installation of the fixed backing, this arrangement reduced the slippage to 0.01–0.02 in. which was considered to be the irreducible minimum. All the data included in this report are from welds made after the fixed backing was installed.

The thermocouples, made from 0.012-in. diam chromel-alumel-duplex wire, were welded securely to the bottom of the thermocouple holes after the specimens were placed in the welder jaws. A 300-mfd bank of condensers, previously charged to 300 v, was discharged through the specimen-thermocouple contact in order to produce intimate bonding between the thermocouple hot junction and the bottom of the thermocouple hole. Thermocouples were located at distances approximately 0.2, 0.3, 0.4, 0.5, 0.6, 0.7 and 0.8 in. from the initial flashing interface. The exact location of each thermocouple was determined from radiographs of each specimen made before and after welding. A typical radiograph is reproduced in Fig. 1*a* showing the location of the thermocouple holes before welding, and the location of the thermocouple holes after welding is illustrated by the radiograph shown in Fig. 1*b*.

The output of the seven thermocouples was fed into a recording oscillograph and a continuous record of

Table 1—Composition, %, of the Steels Employed for Metallographic Studies and Tensile Testing

Steel	*Heat No.*	*C*	*P*	*S*	*Si*	*Mn*	*Cr*	*Mo*	*Ni*
AISI 1020	(Nominal)	0.18–0.23	0.04 max	0.05 max	..	0.30–0.60	..	..	..
AISI 4130	H34362A	0.295	0.014	0.018	0.25	0.53	0.95	0.21	..
AISI 4340	H34308A	0.385	0.013	0.022	0.23	0.78	0.80	0.25	1.74

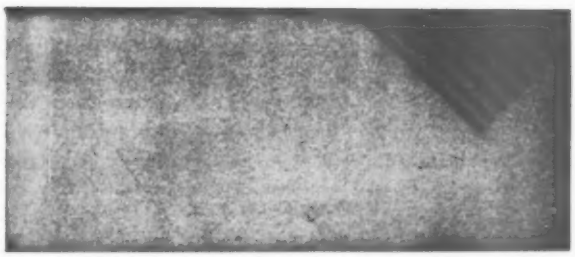


Fig. 1a Typical radiograph before welding

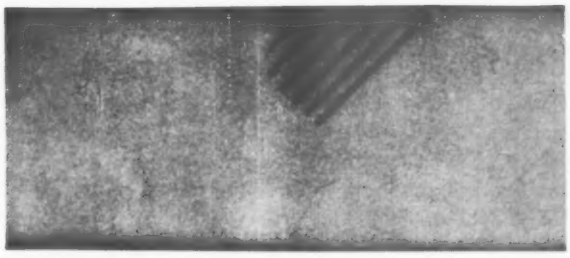


Fig. 1b Typical radiograph after welding—showing collapse of thermocouple holes produced by upset

platen travel, the temperature at each thermocouple location and the force exerted at upset were obtained as a function of time. The oscillographic records were taken for the entire cycle, from prior to the initiation of flashing until the weld had cooled to at least 200° F. Figure 2 shows a typical oscillographic record of the type obtained in this investigation. The traces of thermocouple temperatures, platen force and platen travel are indicated, together with the times of initiation of flashing and of upset. For each combination of welding conditions investigated, four duplicate welds were made and suitable records were obtained in order to permit elimination of random errors.

After removal of the flash by abrasive-belt grinding the location of the centerline was revealed by etching with a 10% aqueous solution of nitric acid and a 0.010-in. diam wire was taped in place at the centerline. A radiograph was then made, and the thermocouple to centerline distances were measured from the radiograph to the nearest 0.01 in. This centerline-locating

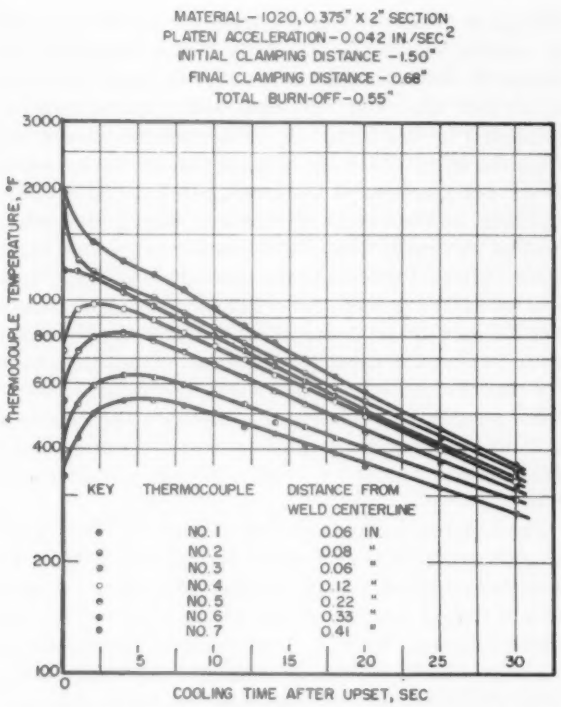


Fig. 3 Typical weld cooling curves—thermocouple temperature as a function of time after upset

procedure was checked by preparing a few weld specimens which had insufficient upset travel and showed a visible line of demarcation at the weld center. When the centerline was located by the etching technique and the specimen radiographed, the radiographic method was shown to be accurate within ±0.01 in.

Treatment of the Data

Figure 3 summarizes the temperature data obtained from a typical experimental flash weld. Each of the seven curves represents a plot of the temperature as a function of time after upset for one particular thermocouple location. Since four duplicate experimental runs were made at each combination of machine settings,

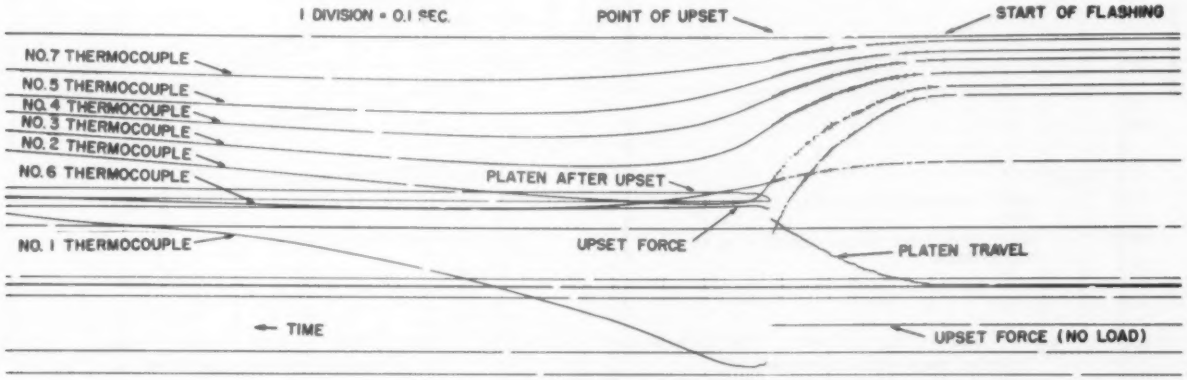


Fig. 2 Typical oscillographic record

four plots similar to Fig. 3 were obtained for each set of welding conditions. Because it was impossible to locate the thermocouples at exactly the same distances in all four specimens, the data could not be directly compared in this form. A further complication arose from the effect of the upsetting action on the locations of the hot junctions of thermocouples 1, 2 and 3. For example, in the case of the data in Fig. 3, the radiographic determination of the location of the hot junctions indicated that thermocouples 1 and 3 were both located at 0.06 in. from the weld line. This is obviously not the case, however, since the indicated temperatures do not agree, and therefore compensation must be made for this effective change in hot junction location. For these reasons, it was necessary to subject the data to a tedious averaging process, using the technique outlined below in order to obtain average data in a more usable form.

The first step in the averaging process involved plotting temperature as a function of distance from the weld line for various instantaneous times after upset. Figure 4 is a typical example of the results obtained by this operation, and shows the temperature as a function of distance exactly 10 sec after upset. Additional plots of a similar nature were also made for times of 0, 2, 4, 6, 8, 12, 20 and 30 sec after upset. The seven solid black points shown in Fig. 4 represent the temperatures indicated in Fig. 3 by the seven thermocouples, 10 sec after upset. The open circles represent similar data obtained from the other three welds made with the same welding conditions.

The effect of the forging action accompanying upset may be noted in Fig. 4. The scatter in the instantaneous temperature points in the vicinity of 0.10 in. results from the previously mentioned uncertainty in the determination of the hot junction locations near the weld line. However, when all the instantaneous temperature data are plotted on a logarithmic scale, the average temperature gradient in the specimen may be readily established.

The average temperature gradients existing in the specimens at times of 0, 2, 6, 10, 20 and 30 sec after upset are indicated in Fig. 5. For greater clarity, the temperature gradients after 4, 8 and 12 sec of cooling have been omitted from this figure.

If true Newtonian cooling were obtained, it would be expected that all plots of the logarithm of temperature as a function of distance would appear as straight lines. However, the excess metal extruded as flash during upset distorts the temperature distribution after upset for several seconds. This is evident from the nonlinearity of the plot of logarithm of temperature vs. distance for 0 time in Fig. 5. Under some conditions this distortion persists for a short time, but in all cases after a comparatively few seconds, the effect is no longer noticeable, and a true exponential gradient is obtained. Since experimental difficulties made exact determination of the temperature at the weld line impossible at the instant of upset, the melting point of the material (2750° F) was arbitrarily chosen as representing the upper limit of possibility.

After the temperature distribution at certain critical intervals of cooling time had been plotted as shown in Fig. 5, the next operation was to use these data to

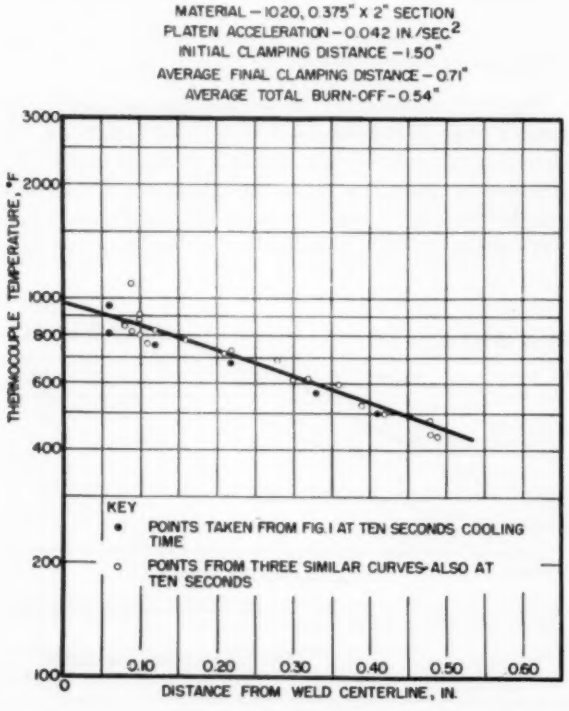


Fig. 4 Averaged temperature gradient—ten seconds after upset

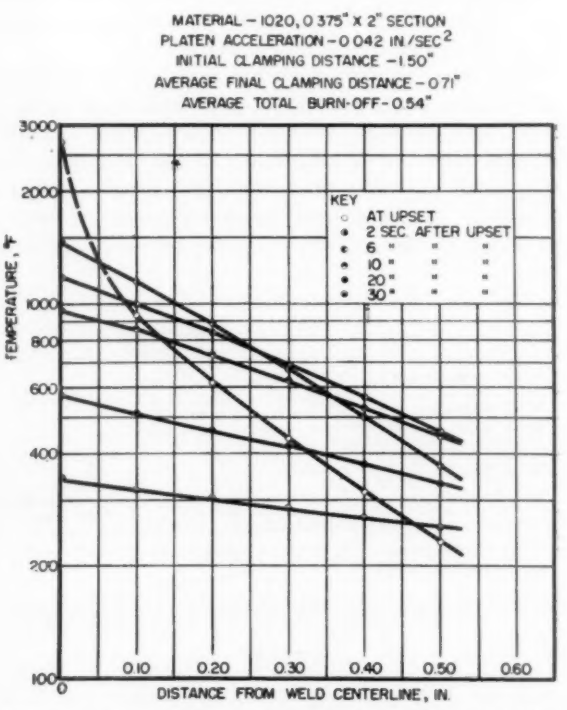


Fig. 5 Averaged temperature gradients—varied cooling times

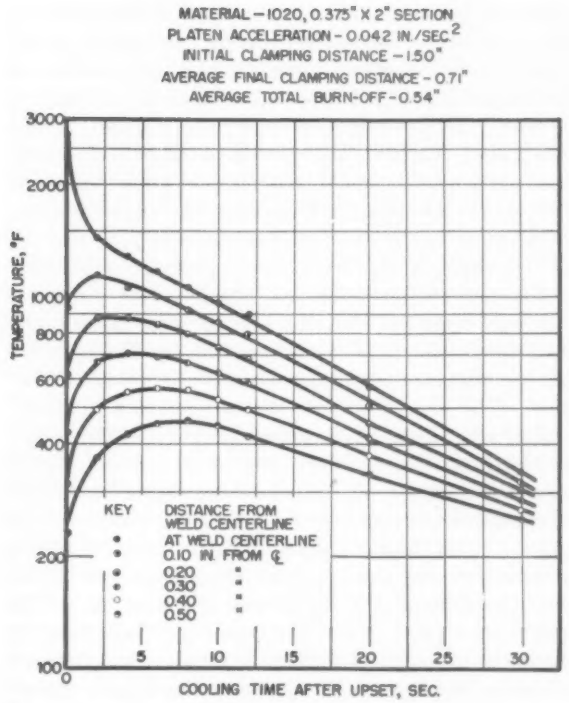


Fig. 6 Averaged weld cooling curves—temperature as a function of time after upset

obtain the averaged cooling curves illustrated in Fig. 6, using the technique outlined below:

1. Six arbitrarily chosen distances, 0.0, 0.1, 0.2, 0.3, 0.4 and 0.5 in. were marked off on the temperature gradients such as are shown in Fig. 5.

2. The average temperature at each of these distances was obtained from the appropriate temperature gradient for times of 0, 2, 4, 6, 8, 12, 20 and 30 sec after upset, using the temperature gradient plots of which Fig. 5 is a typical example.

3. By replotting these values of average temperature as a function of time, a family of curves showing the average cooling behavior at the six arbitrarily chosen distances from the weld line was obtained.

Figure 6, produced from Fig. 5 by the above technique, summarizes the average cooling behavior after upset for welds made using 0.042 ips² platen acceleration 1.50 in. initial clamping distance, 0.54 in. average total burn-off and an average of 0.13 in./specimen upset.

The curves of Fig. 6 for the thermal cycles near the weld centerline which attain temperatures above the lower critical temperature, were replotted using an expanded scale and the average cooling rates at 1300, 1000 and 900° F were determined by the slope method.

Results of the Cooling Rate Studies

A complete tabulation of the welding conditions associated with each flash weld made in the cooling rate portion of this investigation will be found in the Appendix. The initial clamping distance, platen acceleration, total flashing burn-off, total upset distance, upset force, upset distance and final clamping distance* associated with each weld are found in tabular form for both the 0.250- x 2.00-in. and the 0.375- x 2.00-in. specimen sizes. As may be seen by inspection of the tables in the Appendix, four duplicate welds were made with each combination of welding variables investigated. Minor variations in certain of the welding variables may be noted within each group of four duplicate welds; and therefore, the average value of each variable, obtained

* Throughout this report, the term "final clamping distance" indicates the total distance between the clamping jaws of the flash welder at the completion of the welding operation.

Table 2—Welding Conditions Employed in Preparing Specimens for Cooling Rate Determination (Averaged Values from the Appendix)

Group	*Initial clamping distance, in.*	*Average total burn-off, in.*	*Average total upset, in.*	*Average platen travel, in.*	*Average final clamping distance, in.*	*Cooling rate at weld center, °F/sec at: 1300° F*	*1000° F*	*900° F*
AISI 1020 Steel, 0.250- x 2.00-in. section; Approximate Burn-off, 0.5 in.								
Platen acceleration, 0.120 ips²								
A	1.00	0.56	0.19	0.75	0.25	365	280	260
B	1.20	0.56	0.26	0.82	0.38	170	145	125
C	1.50	0.51	0.30	0.81	0.69	115	70	65
Platen acceleration, 0.042 ips²								
D	1.20	0.55	0.32	0.87	0.34	150	125	120
E	1.50	0.46	0.36	0.82	0.68	70	55	55
F	2.00	0.45	0.34	0.79	1.21	45	35	35
Platen acceleration, 0.0166 ips²								
G	1.20	0.55	0.33	0.89	0.32	140	140	145
H	1.50	0.47	0.37	0.84	0.66	80	60	50
I	2.00	0.49	0.34	0.83	1.17	40	30	30
AISI 1020 steel, 0.375- x 2.00-in. section; platen acceleration, 0.042 ips² Approximate burn-off, 0.5 in.								
J	1.20	0.58	0.23	0.82	0.38	155	125	110
K	1.50	0.54	0.26	0.79	0.71	75	45	40
L	2.00	0.55	0.25	0.80	1.20	60	25	25
Approximate burn-off, 0.7 in.								
M	1.20	0.75	0.15	0.90	0.31	215	200	190
N	1.50	0.72	0.17	0.89	0.62	100	75	70
O	2.00	0.76	0.15	0.91	1.09	60	40	35

from all four duplicate runs, was taken as representative for the group.

Table 2 below summarizes the average value of each of the variables together with the averaged cooling rate data for each of the 15 groups of four duplicate runs. Table 2 shows the cooling rates at the weld centerline, measured at 1300, 1000 and 900° F. These cooling rates were obtained from the measured thermal cycles by the method outlined in the previous section, and represent the average values for the four duplicate welds in each group. The code letter in the left-hand column of Table 2 relates the averaged data to the specific groups of data listed in the Appendix.

The cooling rates at the weld centerline were chosen for two reasons:

1. The relatively steep temperature gradients characteristic of flash welding localize the region in which the lower critical temperature is exceeded to a narrow band about the weld centerline. The maximum width of this band in which austenitization occurs was found to be slightly under 0.1 in. on each side of the weld centerline; and therefore, cooling rates at distances greater than 0.1 in. would be of no significance.

2. The most important cooling rate from the metallurgical standpoint is the maximum cooling rate experienced at any point where austenitization occurred. In all cases, this maximum cooling rate was experienced at the weld centerline.

The maximum rate of cooling at the weld centerline encountered in this investigation was 365° F/sec at 1300° F. The welding conditions which produced this fastest cooling rate included a high rate of platen acceleration, 0.120 ips², and an extremely short final clamping distance, 0.25 in., both of which contribute to faster cooling. The slowest cooling rate, 40° F/sec at 1300° F, was obtained using a platen acceleration of 0.0166 ips² and a final clamping distance of 1.17 in.

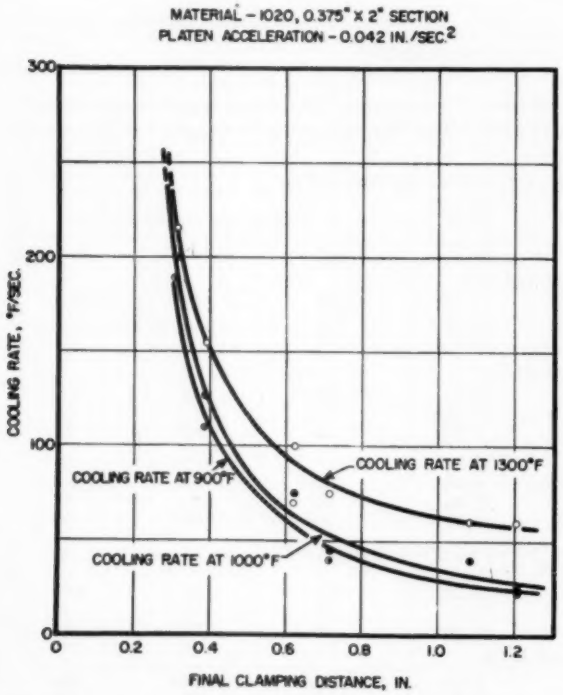


Fig. 7 Effect of final clamping distance on the cooling rate at the weld line

When this investigation was first initiated it was anticipated that the cooling rates obtained in the weld zone in flash welds would be dependent upon two major factors: (1) The length of the heat-flow path from the weld region to the water-cooled clamping jaws and (2) the steepness of the temperature gradient established in the specimen at the instant of upset.

It was apparent that the first of these factors, the heat-flow path length, could be readily studied by varying the final clamping distance and the specimen thickness. The second factor, the temperature gradient, could be investigated by proper selection of the platen acceleration, the specimen thickness and the initial clamping distance, which have been shown previously to control the temperature distribution at the instant of upset.[1, 2] Of these last three variables, only the platen acceleration and the specimen thickness could be independently varied in the present investigation. This results from the fact that the initial and final clamping distances are related through the burn-off and upset distances employed. Therefore, for each final clamping distance studied, the initial clamping distance was fixed by the choice of burn-off distance and upset distance.

Effect of the Final Clamping Distance. The effect of the final clamping distance upon the cooling rate at the weld centerline is illustrated in Fig. 7. As would be expected, a decrease in the final clamping distance results in an increase in the cooling rate experienced by the specimen. The range of final clamping distances studied was from 0.3 to 1.2 in., which correspond to initial clamping distances of 1.2 and 2.0 in., respectively. The data of Fig. 7 were obtained using a constant platen acceleration of 0.042 ips² with 0.375-in. specimens. The effect of final clamping distance on the cooling rates at 1300, 1000 and 900° F may be readily seen by inspection of this plot.

It is apparent that a reduction in the length of the heat-flow path caused by reducing the final clamping distance increases the cooling. For example, reducing the final clamping distance from 0.8 to 0.35 in. causes an increase in the cooling rate at the weld centerline from approximately 75° F/sec at 1300° F to 180° F/sec at 1300° F. A comparable increase in the cooling rates at 1000 and 900° F also results as may be verified by inspection of Fig. 7. At final clamping distances greater than 0.8 in., the cooling rates are not as markedly dependent on minor variations in distance. For example, increasing the final clamping distance from 0.8 to 1.2 in. only lowers the cooling rate from 75° F/sec at 1300° F to about 60° F/sec at 1300° F.

Effect of Platen Acceleration. All other conditions being equal, an increase in the platen acceleration during flashing results in a steeper temperature gradient in the specimen at the initiation of upset, as has been shown previously.[1, 2] The volume of metal extruded

as flash and the resulting upset distance are also directly influenced by the temperature gradient. To investigate the effect of the temperature gradient at the instant of upset on the subsequent cooling rate, weld specimens were prepared at three rates of platen acceleration, 0.120, 0.042 and 0.0166 ips^2, using AISI 1020 steel of 0.250- x 2.00-in. section.

The results of this study are given in Fig. 8. It appears that the rate of cooling after upset is increased by the faster rates of platen acceleration. Results of this investigation also showed that the steeper temperature gradients associated with the faster rates of platen accelerations result in a reduction in the volume of metal extruded as flash. For example, by reference to the average data for groups B, D and G, in Table 2, it may be seen that the total upset distance was less the faster the platen acceleration. With platen accelerations of 0.120, 0.042 and 0.0166 ips^2, respectively, the upset distances which resulted in stopping the machine were found to be 0.26, 0.32 and 0.33 in., respectively. It should also be noted that the greatest variation in the upset distance required to stop the machine was encountered between welds using the fast platen acceleration of 0.120 ips^2 and the intermediate platen acceleration of 0.042 ips^2. This fact appears to be in agreement with the observed effects on the cooling rates, since a definite difference in cooling rate is observed between welds made with 0.120 ips^2 and 0.042 ips^2 acceleration rates. On the other hand, little significant difference may be noted in cooling rate between welds made at 0.042 and 0.0166 ips^2 in Fig. 8. It may be assumed, therefore, that this smaller volume of hot metal extruded during upset with the fast acceleration, acts as a smaller heat source during cooling, thus accounting for the increase in the cooling rate when the fast acceleration is employed.

It is important to note in Fig. 8, that at final clamping distances less than 0.5 in. the final clamping distance is the most important variable affecting the cooling rate. On the other hand, at final clamping distances greater than 0.5 in., the effect of platen acceleration becomes significant in determining the cooling rate, since in this range of final clamping distances, the effect of the final clamping distance is less pronounced.

Effect of Specimen Thickness. The results of an investigation into the effect of a change in section thickness on the cooling rate are shown in Fig. 9. This figure indicates a trend toward slightly more rapid rates of cooling as the thickness of the material is increased. However, it should be noted that this trend may not be consistent at larger values of section thickness than were studied in this investigation.

In any consideration of the effect of the section thickness on the cooling rate it must be recalled that the section thickness is a factor which influences both the length of the heat-flow path to the water-cooled clamping jaws and the steepness of the temperature gradient. As the thickness of the material being welded is increased, the length of the heat-flow path increases, resulting in a decreased rate of cooling. Conversely, it has been shown in a previous report[1, 2] that a similar increase in specimen thickness will steepen the tempera-

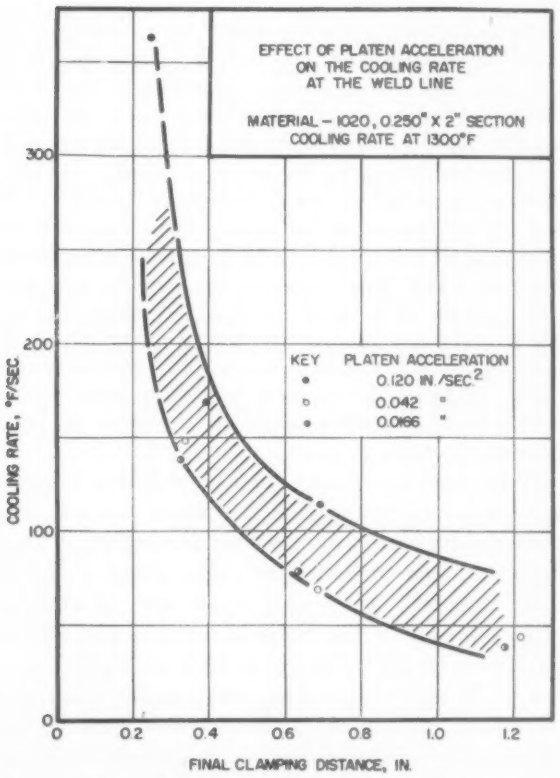


Fig. 8 Effect of platen acceleration on the cooling rate at the weld line

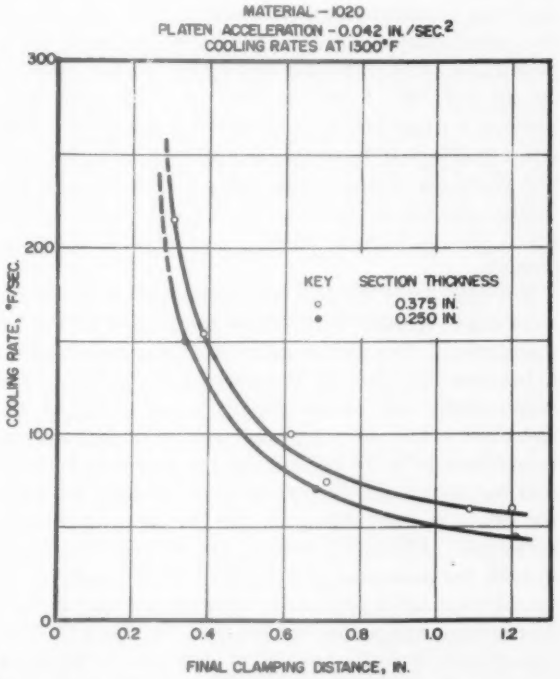


Fig. 9 Effect of section thickness on the cooling rate at the weld line

ture gradient established in the specimen during flashing, thereby reducing the volume of hot metal extruded as flash and resulting in an increase in the subsequent cooling rate. It is evident that for the particular conditions investigated, involving an increase in thickness from 0.250 to 0.375 in., the temperature gradient effect of the increased thickness has been the controlling factor. It is possible that these two conflicting effects associated with a change in thickness may be occurring at different rates in a manner such that at still greater thicknesses the heat-flow path effect might dominate, resulting in a decreased rate of cooling. However, at the present time there is no experimental evidence to support such an assumption.

Part II

PREPARATION OF SPECIMENS FOR METALLOGRAPHIC EXAMINATION AND MECHANICAL TESTING

After the effect of welding variables on the cooling rate had been determined it was possible to prepare welds having predetermined rates of cooling after upset, in steels of different hardenability. This program was adopted as a check on the practical significance of the experimentally determined cooling rates, and also to explore the possibility of correlating the microstructure and properties of these welds using the concepts of hardenability.

Welds were prepared employing AISI 1020, 4130 and 4340 steels and subjected, in both the as-welded and normalized condition, to metallographic examination, hardness measurement and tensile testing. Specimens for metallographic examination were prepared using conditions which provided cooling rates after upset of 50, 85 and 240° F/sec, at 1300° F. All welds were made at a single platen acceleration of 0.042 ips^2, using either 0.250- x 2.00- or 0.375- x 2.00-in. material, and the clamping distance was adjusted to provide the desired cooling conditions. In all cases, the current cutoff was performed within $^1/_2$ cycle after upset initiation.

For each set of welding conditions studied, ten welds were made in each of the three steels used in this investigation. One weld from each set was employed for a hardness traverse in the as-welded condition, and subsequently for metallographic examination of the as-welded condition. A second weld from each set was normalized prior to performing the hardness traverse and the metallographic examination in order to study the effect of normalizing on the hardness and microstructure. Additional weld specimens were employed in both the as-welded and the normalized condition for tensile tests, using procedures outlined in a later section. Normalizing temperatures were 1655, 1625 and 1575° F, respectively, for the AISI 1020, 4130 and 4340 steels, the time at temperature being 20 min in all cases. The remaining specimens have been stored in order that correlation may be made with future welds in the event that other testing procedures are found to be desirable as a result of future work.

It was found during this portion of the investigation, that although the temperature distribution at the instant of upset was essentially independent of the chemical analysis of the steel used, the behavior of the steel during upset varied considerably for the three steels. Since the thermal and electrical properties of the three steels are known to be very similar, it is obvious that identical flashing conditions lead to the production of identical temperature distributions in the three steels. However, since the elevated temperature strength is not the same for the three steels, the amount of upset produced by a given upset force varies inversely with the high temperature strength. Thus, in all cases with the same temperature gradient at the instant of upset and the same upset force, the upset distance obtained was of the same order of magnitude for both the AISI 4340 and 4130 specimens, and a greater amount of upset was always obtained with the AISI 1020 steels. This would be expected in view of the marked effect of alloying additions in increasing the strength of steels at elevated temperatures.

This difference in upsetting behavior due to differences in the elevated-temperature strength introduced a complication in the selection of equivalent welding conditions for the three grades. For the purpose of the present investigation it was desired to select welding conditions which would produce equivalent cooling rates in the welds made in the three grades of steel. Since, as has been previously shown, the most influential factor in determining the cooling rate is the final clamping distance, and since variations in the upset distance influence the final clamping distance, allowance must be made for differences in the upsetting action if the same cooling rates are to be obtained. For this reason it was found necessary to increase the amount of burn-off by an amount just equivalent to the reduction in upset distance experienced by the alloy steels in order that the same final clamping distance be realized. This increase in burn-off for the alloy steels had no effect on the temperature distribution at the instant of upset, since it was shown previously[1, 2] that once the stable temperature gradient has been established, further flashing action produces no change in the temperature gradient at upset.

Considering the possible effect of a reduction in upset distance on the cooling rate, it is found that two self-compensating factors are involved, both of which were discussed in some detail in Part I of this report.

1. With the less readily upset alloy steels, the reduced volume of hot metal extruded as flash at the weld line results in a slightly increased cooling rate.

2. The reduction in upset travel results in a slight increase in the length of the heat-flow path to the clamping jaws, and therefore, in a slower rate of cooling.

Since, as far as the rate of cooling is concerned, the changes due to these factors are not likely to be of large

magnitude, and since they are essentially self-compensating, it was assumed for purposes of this report that the experimentally determined cooling rate data for welds employing AISI 1020 steel are directly applicable to welds made with AISI 4130 and 4340 steels. The validity of this assumption will be checked in future work by experimental determination of the cooling rates in similar welds employing the alloy steel.

Although thermocouples were not attached to these specimens which were made for metallographic examination and physical testing, an oscillographic record was made of each weld cycle, from the initiation of flashing until shortly after upset. It was thus possible to obtain a record of the platen travel and upset force, and also to detect partial butting or the accidental flow of upset current.

Preparation of Specimens for Metallographic Examination and Hardness Traverses

The weld specimens prepared using conditions given in parts (*a*) and (*b*) of Table 3, were cut along the centerline of the 2.0-in. width using a water-cooled abrasive cutoff wheel. The two cut surfaces were used for hardness measurement and metallographic examination after carefully grinding away the excess flash near the weld line. Hardness traverses were taken along the centerline of the width of these cut surfaces, and the photomicrographs included in this report were taken of the microstructures along this line, normal to the weld. Prior to the adoption of the above technique several longitudinal sections were prepared normal to the 2.0-in. width of an alloy steel weld specimen and hardness traverses were made along the centerlines of the resulting sections. These hardness traverses indicated that no significant differences in structure were to be found across the 2.0-in. width of the specimen and therefore the above method was adopted.

Preparation of Specimens for Tensile Testing

At each of the four cooling conditions listed in part (*c*) of Table 3, two weld specimens were prepared employing each of the three steels of differing hardenability

Table 3—Summary of the Conditions Used for Preparation of Welds at Predetermined Cooling Rates

Material—AISI 1020, 4130 and 4340; platen acceleration—0.042 ips²; burn-off—adjusted to produce the desired final clamping distance (in all cases 0.5 in. or greater total burn-off was employed)

Section size, in.	*Initial clamping distance, in.*	*Final clamping distance, in.**	*Centerline cooling rate, ° F/sec @ 1300° F*
(*a*) Specimens for metallographic examination			
0.250 x 2.00	1.0	0.27	240
0.375 x 2.00	1.5	0.67	85
0.375 x 2.00	2.0	1.26	50
(*b*) Specimens for hardness measurement			
0.250 x 2.00	1.0	0.27	240
0.375 x 2.00	1.0	0.27	260
0.375 x 2.00	1.5	0.67	85
0.375 x 2.00	2.0	1.26	50
(*c*) Specimens for tensile testing			
0.250 x 2.00	1.0	0.27	240
0.375 x 2.00	1.0	0.27	260
0.375 x 2.00	1.5	0.67	85
0.375 x 2.00	2.0	1.26	50

* Plus or minus 0.01 in.

used in this investigation. One of each pair of welds prepared from the same steel, at the same cooling conditions, was subjected to a normalizing treatment prior to machining.

Each of the resulting 24 weld specimens, initially 2 in. wide and 11 in. long, was slit longitudinally along the center of the 2.0-in. width using a water-cooled abrasive cutting-off wheel in order that two rough blanks could be obtained for testing from each weld specimen. Surface irregularities and scale were removed by surface grinding the blanks to a uniform width of 0.770 ± 0.003 in. and a thickness of 0.220 in. or 0.345 ± 0.003 in., depending on the original thickness of the weld specimen. To promote a larger percentage of failures within the heat-affected zone, the bars were notched at the weld centerline an equal depth from each side, so that the width of the smallest section was 0.600 ± 0.003 in. A grinding wheel of $^1/_2$-in. thickness, dressed to have an edge radius of $^1/_4$-in. was used for the notching operation, and the width of the notch, on the 0.220- or 0.345-in. thickness of the completed tensile specimen, was used

Table 4—Welding Conditions Employed in Preparing Specimens for Metallographic Examination

Platen acceleration—0.042 ips²

Steel	*Thickness, in.*	*Initial clamping distance, in.*	*Total burn-off, in.*	*Total upset distance, in.*	*Final clamping distance, in.*	*1300° F Cooling rate at weld centerline, ° F/sec*	*Condition*	*Fig. No.*
1020	$^1/_4$	1.00	0.51	0.22	0.27	240	As-welded	10
1020	$^1/_4$	1.00	0.50	0.23	0.27	240	Normalized	11
1020	$^3/_8$	1.50	0.56	0.27	0.67	85	As-welded	12
1020	$^3/_8$	2.00	0.52	0.22	1.26	50	As-welded	13
4130	$^1/_4$	1.00	0.52	0.21	0.27	240	As-welded	14
4130	$^1/_4$	1.00	0.51	0.22	0.27	240	Normalized	15
4130	$^3/_8$	1.50	0.67	0.16	0.67	85	As-welded	16
4130	$^3/_8$	2.00	0.58	0.16	1.26	50	As-welded	17
4340	$^1/_4$	1.00	0.54	0.19	0.27	240	As-welded	18
4340	$^1/_4$	1.00	0.53	0.20	0.27	240	Normalized	19
4340	$^3/_8$	1.50	0.66	0.17	0.67	85	As-welded	20
4340	$^3/_8$	2.00	0.59	0.15	1.26	50	As-welded	21

as the gage length for finding the per cent elongation. This gage length was of the order of 0.37 in.

Results of the Metallographic Examination

Metallographic examination of the three steels in the

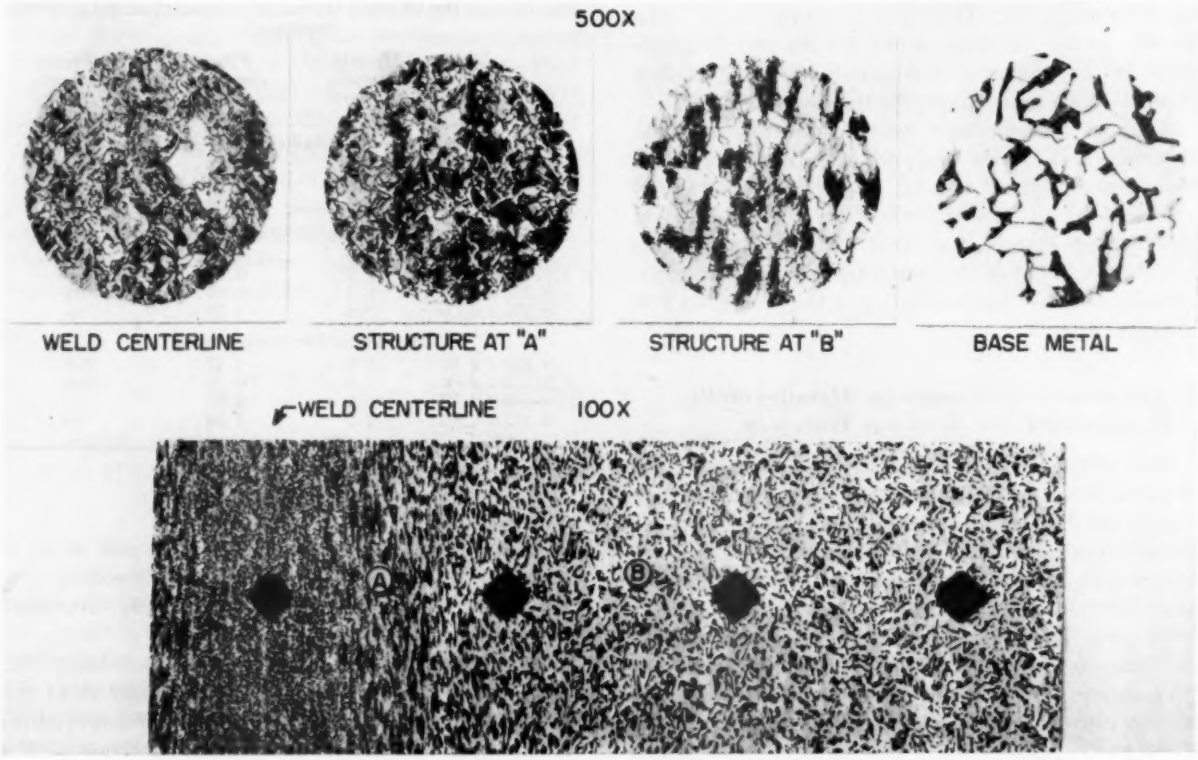


Fig. 10 Photomicrographs of flash weld in 1020 steel, weld centerline cooling rate 240° F/sec at 1300° F, as-welded

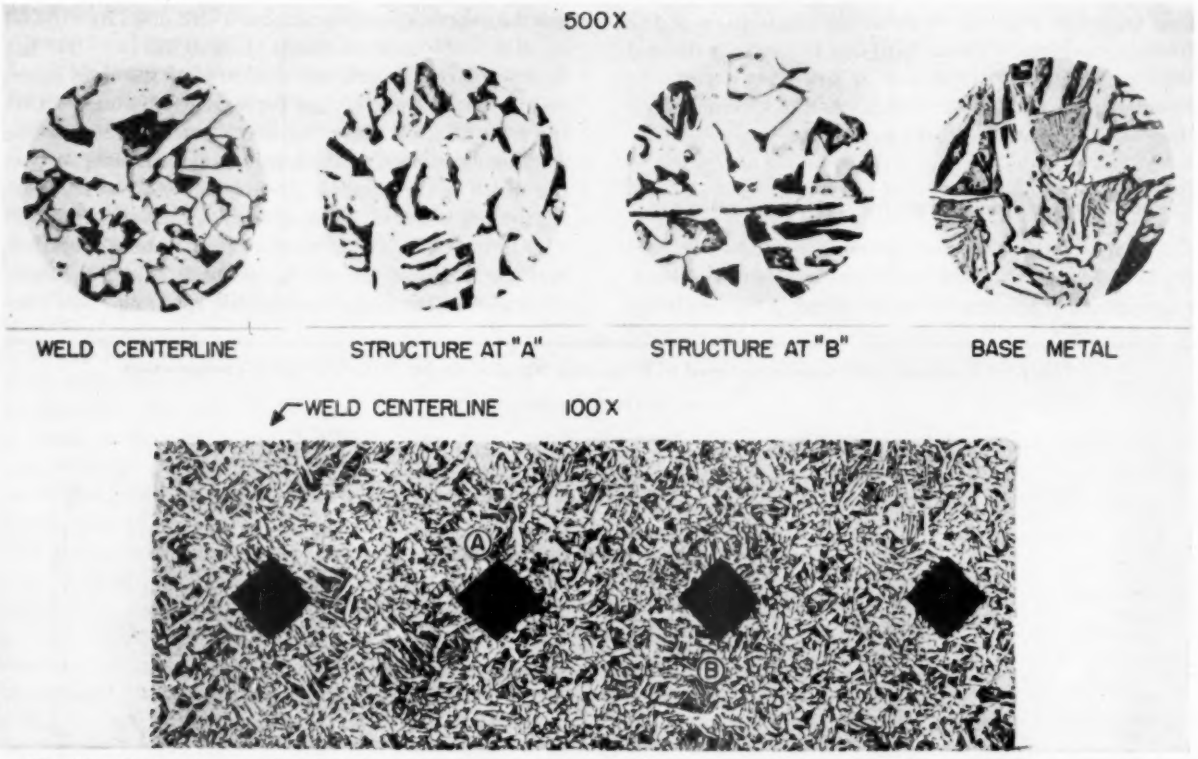


Fig. 11 Photomicrographs of flash weld in 1020 steel, weld centerline cooling rate 240° F/sec at 1300° F, normalized

as-received condition revealed considerable decarburization of one surface in some bars of the 0.250-in. AISI 4130 steel. Other material and thicknesses appeared free of this defect. Banding was quite apparent in both the AISI 4130 and 4340 steels in the as-received condition, and was slightly more noticeable in the AISI 4130 material. When these steels were subjected to the previously described normalizing treatment, the banding in the AISI 4130 steel was almost completely removed while banding in the AISI 4340 steel was not as effectively reduced by normalizing.

Typical microstructures found in the weld region of flash welds in AISI 1020, 4130 and 4340 steels, prepared under conditions listed in part (*a*) of Table 3, are shown in Figs. 10 to 21, inclusive. For each of the three steels employed, a panorama of the weld zone, at 100 × plus four photomicrographs showing representative portions of the microstructure at 500 × magnification are included, and the complete data on welding conditions are listed in Table 4.

To permit comparison of the extent of the heat-affected and forged zone in these welds, Vickers pyramid hardness indentations were located at 0.020-in. intervals, the first indentation at the left being at the weld centerline in all panoramas. The approximate relative hardnesses of the structures in the vicinity of any one weld may be determined by comparison of the sizes of the indentations. However, because of the differing amounts of material removed in the polishing operations, visual comparison of relative hardnesses in different panoramas is not possible.

The amount of forging which occurs in the specimen at upset is readily apparent in the panoramas of the welds in the as-welded condition. All weld microstructure panoramas were taken from a longitudinal section parallel to the rolling direction and normal to the rolled surface of the plate, and in most instances the direction of rolling is clearly evident from the banded appearance of the base metal. The change in the direction of the fiber structure in the vicinity of the weld is also clearly evident in the as-welded specimens, and it should be noted that in all cases the fiber structure at the weld line is transverse to the normal as-rolled structure. In the case of the 1020 steel welds (Figs. 10, 12 and 13) the fiber structure appears to be oriented perpendicular to the rolling direction over an appreciable distance (0.020–0.025 in.) as a result of the general compression of the hot metal in the weld region. In the alloy grades, however, a more gradual change in the fiber structure is evident as may be seen in Figs. 14, 16, 17, 18, 20 and 21.

The result of the increased resistance to upsetting which is associated with flash welds employing alloy steels may be observed in the panoramas of weld microstructure. Comparison of the weld-zone panoramas of Figs. 10, 14 and 18, for welds made in AISI 1020, 4130 and 4340 steels prepared at a centerline cooling rate of 240° F/sec, shows that the heat-affected zone is wider for the alloy steels than for the plain carbon steel. The apparent heat-affected zone extends approximately 0.045 in. from the weld centerline in the

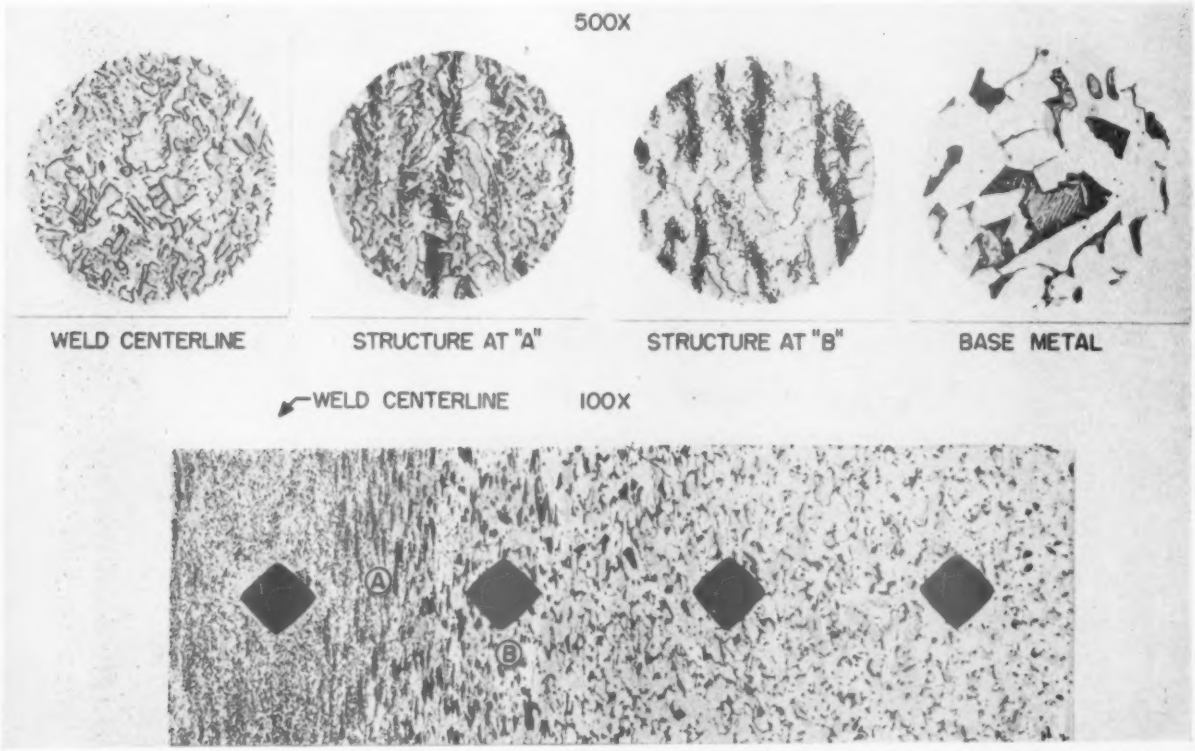


Fig. 12 Photomicrographs of flash weld in 1020 steel, weld centerline cooling rate 85° F/sec at 1300° F, as-welded

4340, 0.040 in. from the weld centerline in the 4130 and only 0.30 in. from the weld centerline in the 1020, as may be seen by inspection of the above panoramas using the spacing of the hardness indentations as distance markers. The following discussion summarizes the factors which contribute to the observed differences in the width of the heat-affected zones.

The elevated temperature strength of the alloy steels is known to be greater than that of the plain carbon steel, and this has been borne out by the reduction in the observed upset distance obtained with flash welds in the alloy grades. This reduction in the upset distance due to the higher elevated-temperature strength has a complex influence on the width of the heat-affected zone of a flash weld, as summarized below.

1. The volume of metal heated above the lower critical temperature at the instant of upset is fixed by the temperature distribution. Thus, the faster the platen acceleration, the shorter the initial clamping distance, and the thicker the specimen, the steeper will be the temperature gradient, and therefore, the smaller will be the volume of metal above the lower critical temperature at the instant of upset.

2. During upset, the temperature distribution changes in a complex manner, since hot metal is extruded at the weld interface as flash, thus providing a high temperature heat reservoir at the sides of the weld line. Heat then flows from this reservoir through the specimens to the clamping jaws, raising the temperature of the material in the vicinity of the weld line, and distorting the temperature distribution.

3. If the upsetting action were identical in various steels, the net effect would be the same for a given set of welding conditions with a given specimen size, and would cause a certain volume to be heated above the critical temperature. This, in turn, would provide heat-affected zones of exactly the same width in all steels, although the microstructure within the heat-affected zones would differ in accordance with the hardenability of the steels.

4. However, in the present research, the available upset force was held constant, and therefore the high temperature strength of the material and the nature of the temperature distribution at upset controlled the amount of upset obtained. Therefore, with a given temperature distribution at the instant of upset, the higher strength alloy steels upset less than the weaker plain carbon steels. As a result, the temperature at the weld line, and at any given distance from the weld line, was higher for the alloy steels due to the smaller upset distance obtained, and thus it is possible to explain the existence of a wider heat-affected zone in the alloy steels. In general, therefore, it may be concluded that with a given upset force, and a given temperature distribution, the heat-affected zone will be wider the greater the elevated temperature strength of the steel.

Figures 12, 16 and 20 illustrate the same effect for conditions which provided a more gradual temperature gradient, and a cooling rate of 85° F/sec at 1300° F at the weldline. Again it may be noted that the heat-affected zone is wider for the alloy steel than for the plain carbon steel, the half width being approximately

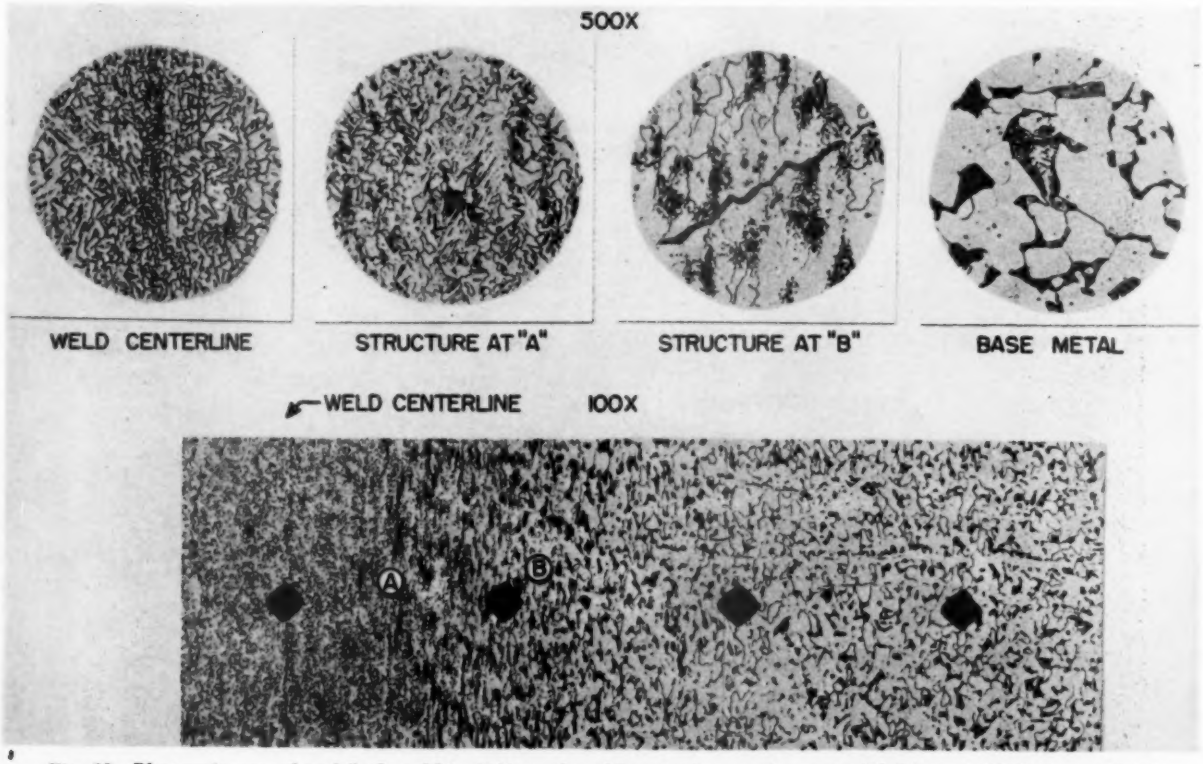


Fig. 13 Photomicrographs of flash weld in 1020 steel, weld centerline cooling rate 50° F/sec at 1300° F, as-welded

0.060 in. for the 4340, 0.050 in. for the 4130 and 0.040 in. for the 1020 steel. It should be borne in mind that the differences in the width of the regions undergoing transformation are of the order of 0.01 in., which in most cases is the extreme limit of reproducibility in upset distance. For this reason, the changes discussed

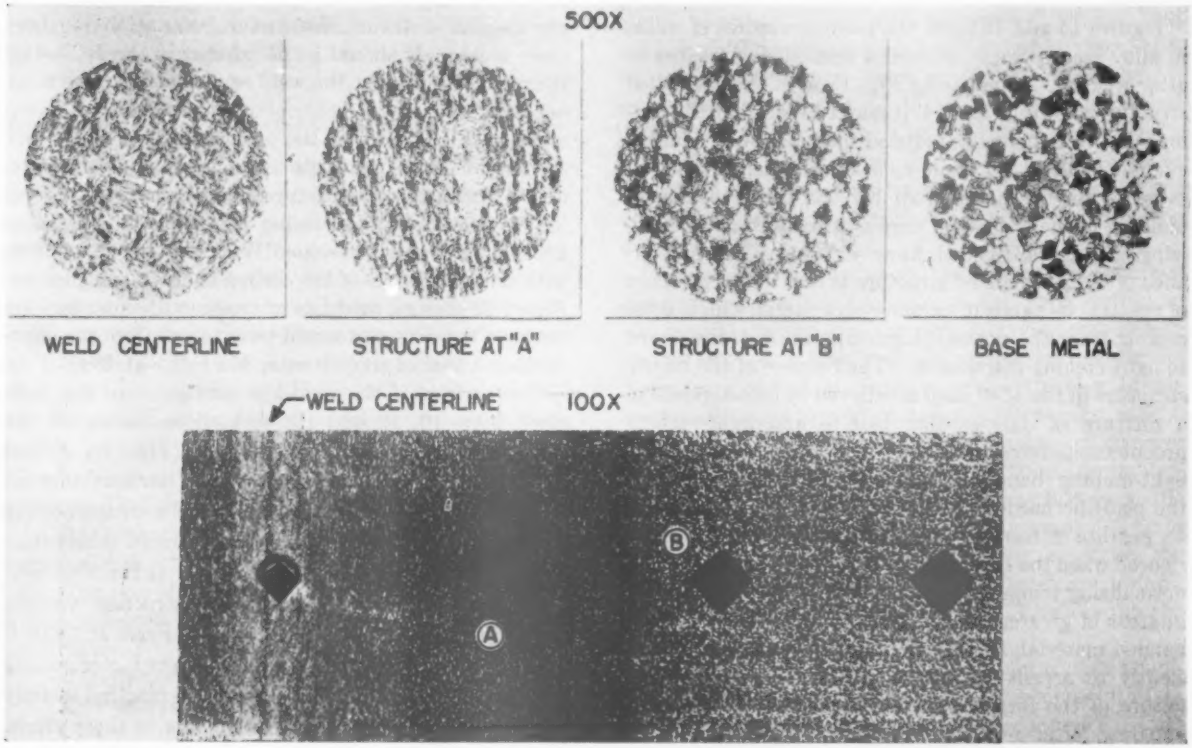


Fig. 14 Photomicrographs of flash weld in 4130 steel, weld centerline cooling rate 240° F/sec at 1300° F, as-welded

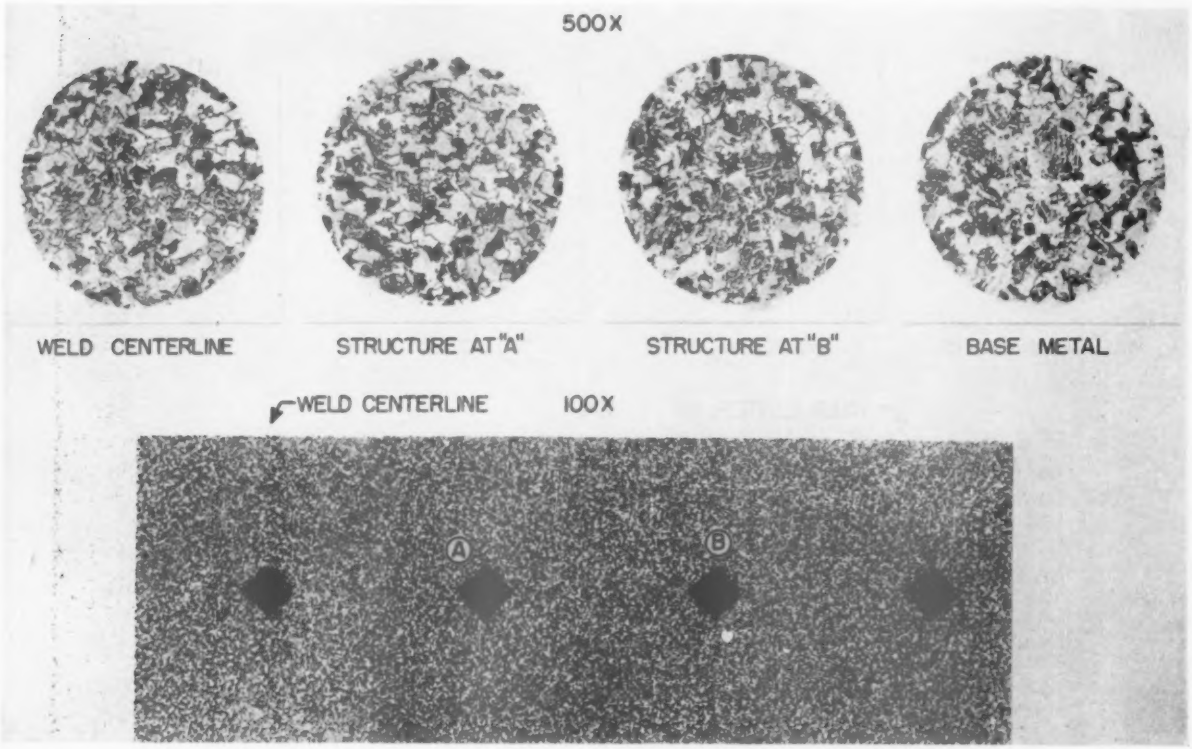


Fig. 15 Photomicrographs of flash weld in 4130 steel, weld centerline cooling rate 240° F/sec at 1300° F, normalized

above are difficult to observe and correlate exactly with temperature measurements. Figures 13, 17 and 21 show a similar effect for a still more gradual temperature gradient.

Figures 15 and 19 show the microstructures of welds in alloy steels which received a normalizing treatment after welding. Comparing Fig. 15 with the as-welded structure shown in Fig. 14, it may be seen that the normalizing treatment has reduced the amount of banding evident in the 4130 grade to a marked degree. However, as may be noted from Fig. 19, the evidences of banding in the 4340 steel were not removed by normalizing. In the 4340 steel, however, the banded appearance of the normalized structure is due to the presence of continuous bands of carbon-rich material which, upon cooling from the normalizing temperature, transformed to light-etching martensite. The balance of the microstructure in the 4340 steel is believed to be composed of a mixture of dark-etching bainite and light-etching proeutectoid ferrite, dispersed between the massive light-etching bands of martensite. In other words, the pearlitic hardenability of the 4340 is so great that no pearlite is formed by the cooling conditions experienced when the test specimens were air cooled from the normalizing temperature. In addition, it appears that in areas of greater than nominal carbon content in the banded material, the hardenability was increased sufficiently to permit transformation to martensite. The nature of the forging flow during upset thus remains apparent after normalizing due to the difference in the etching characteristics of the microconstituents, which emphasize the forging flow lines in the weld region.

The photomicrographs taken of the weld specimens at 500 × magnification have been included to reveal the details of the microstructural variation in these three steels. It should be noted that in the 1020 steel the microstructure at the weld centerline becomes more needlelike as the rate of cooling is increased. For example in Fig. 13, where the cooling rate was 50° F/sec at 1300° F, there is a slight tendency for the formation of a Widmanstätten structure at the weld line, whereas in Fig. 10, where the cooling rate was 240° F/sec at 1300° F, a highly developed Widmanstätten structure with some evidences of low carbon martensite is present. Figure 12 shows a weld-line microstructure intermediate between these two, as would be expected from the intermediate value of cooling rate, 85° F/sec at 1300° F.

Comparison of the weld-line structures in the 1020 steel, Figs. 10, 12 and 13, with those shown for the 4130 (Figs. 14, 16 and 17) and 4340 (Figs. 18, 20 and 21) shows the effect of the increased hardenability on the microstructure at the weld line. The critical cooling rates of the 4130 and 4340 grades is obviously slower than even the slowest cooling rate observed at the weld centerline, since a martensitic weld-line structure was obtained in both steels with even the 50° F/sec at 1300° F cooling rate. As would be expected, the faster cooling rates of 85° F/sec and 240° F/sec also resulted in fully martensitic structures at the weld line in these steels.

Additional inserts have been included with each pan-

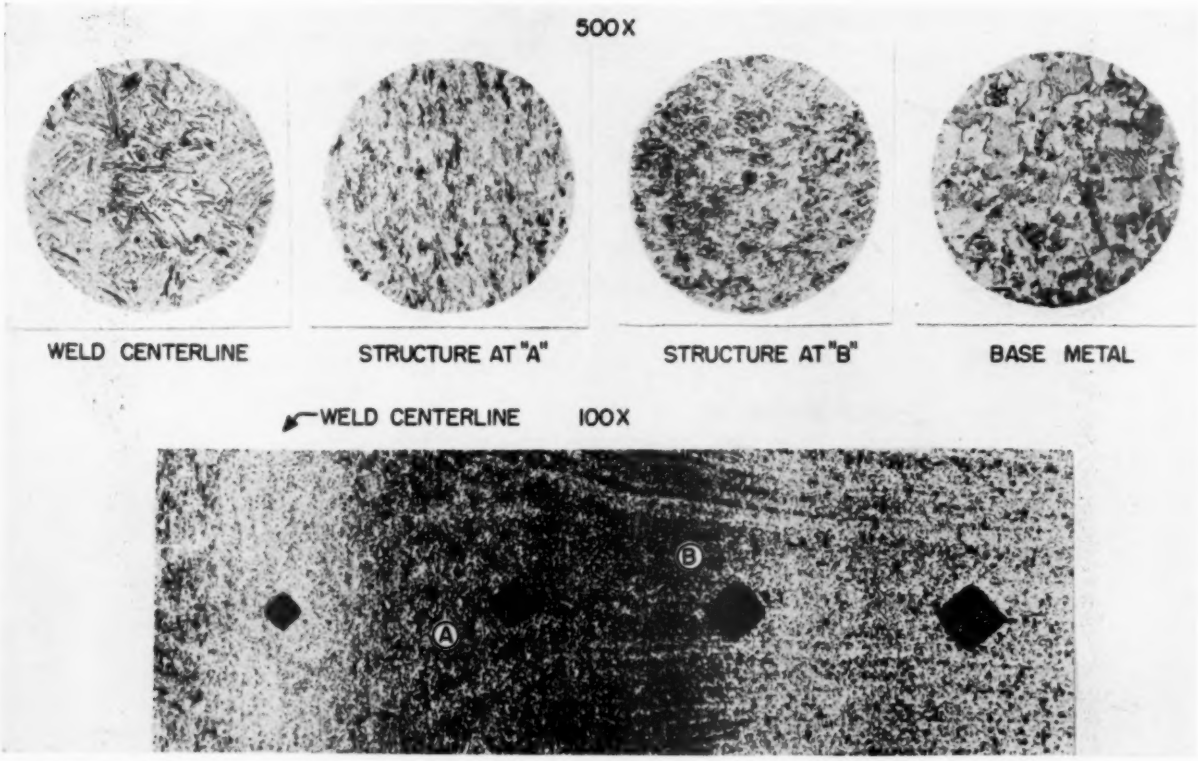


Fig. 16 Photomicrographs of flash weld in 4130 steel, weld centerline cooling rate 85° F/sec at 1300° F, as-welded

orama to show, at 500 × magnification, two intermediate microstructures as well as the original unaffected microstructure of the base metal in each case. It should be noted that the base metal in each case showed a characteristic mixture of ferrite and pearlite reflecting the carbon content of the alloy.

Results of Hardness Traverses

Since hardness measurements are widely used to detect microstructural changes in steels, extensive hardness surveys were conducted during this investigation. In addition to the actual measurement of hardness, cooling rate data, obtained during the investigation, and hardenability data for the steels studied were employed to calculate the approximate hardness at the weld line. The technique for predicting the weld centerline hardness is discussed in the following section, and the results are later listed in tabular form for comparison with the observed values.

The microstructure in the vicinity of a flash weld is determined by the following factors:

1. The maximum temperature experienced at a given point at any time during the welding operation.
2. The rate of cooling experienced by those portions of the specimen previously heated above the critical temperature.
3. The hardenability of the steel being welded.
4. The mechanical working action obtained during upset.

Extensive thermal measurements have indicated that, in the section sizes studied during this investigation, less than 0.10 in. of material on each side of the final weld line ever exceeds the lower critical temperature. In other words, austenitization is restricted to a zone less than 0.2 in. wide, centered about the final weld line. This observation is supported by the photomicrographs of typical welds previously shown, where in no case did the visible heat-affected zone extend more than 0.1 in. from the weld centerline. As a result of this observation, it may be concluded that the production of brittle transformation products will not occur at distances greater than 0.1 in. from the weld centerline.

Of this region heated above the minimum austenitizing temperature, the material at the weld centerline was found to experience the fastest cooling rate during and after upset. This material at the weld centerline therefore is the most likely to transform to a brittle martensitic structure since the critical cooling rate is most likely to be exceeded at this point. Extensive thermal measurements have made it possible to predict the cooling rate at the weld centerline from the welding variables with reasonable accuracy. Therefore, if the effects of various cooling rates on the transformation behavior of a given steel are known, the microstructure and therefore the hardness at the weld centerline may be predicted.

The response of a steel to a variety of cooling conditions may be obtained from Jominy hardenability data for the steel in question. In the absence of accurate hardenability data, it would appear that the safest pro-

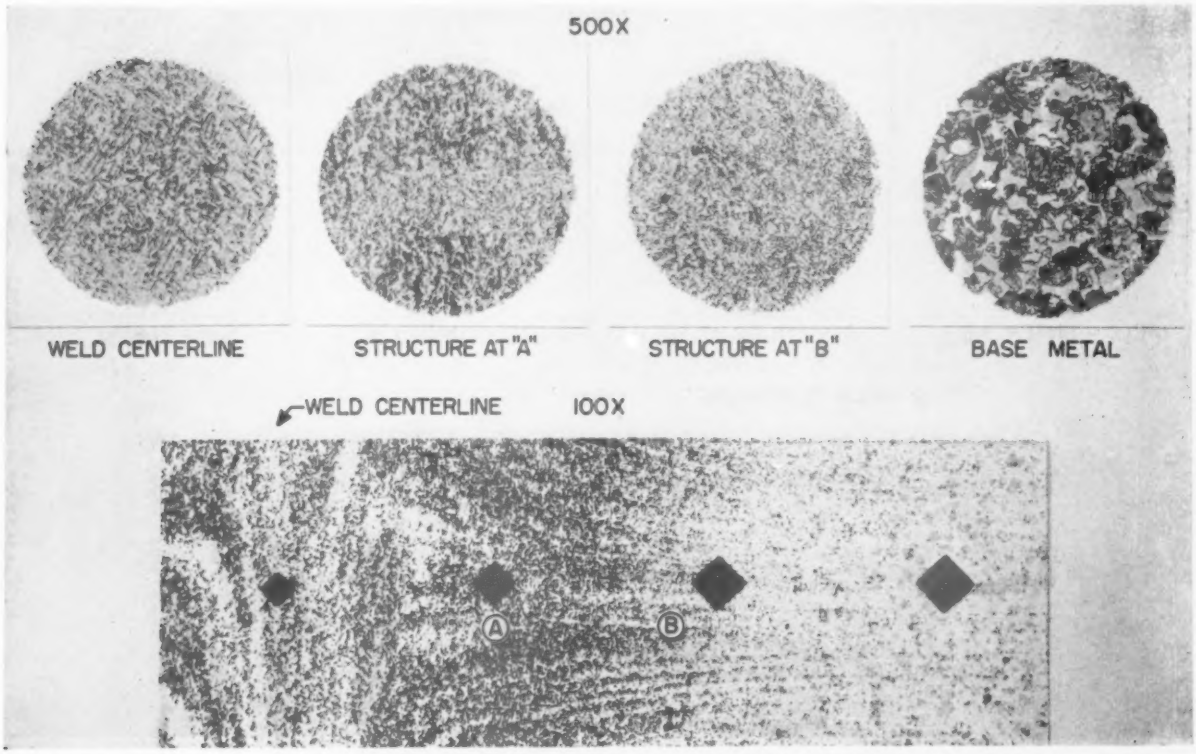


Fig. 17 Photomicrographs of flash weld in 4130 steel, weld centerline cooling rate 50° F/sec at 1300° F, as-welded

cedure would be to base any estimates on the maximum curve of the hardenability band published by the AISI for the so-called H-Steels. Published data on the Jominy hardenability test provide information on the cooling-rate at 1300° F for various distances from the water-quenched end of a Jominy bar.

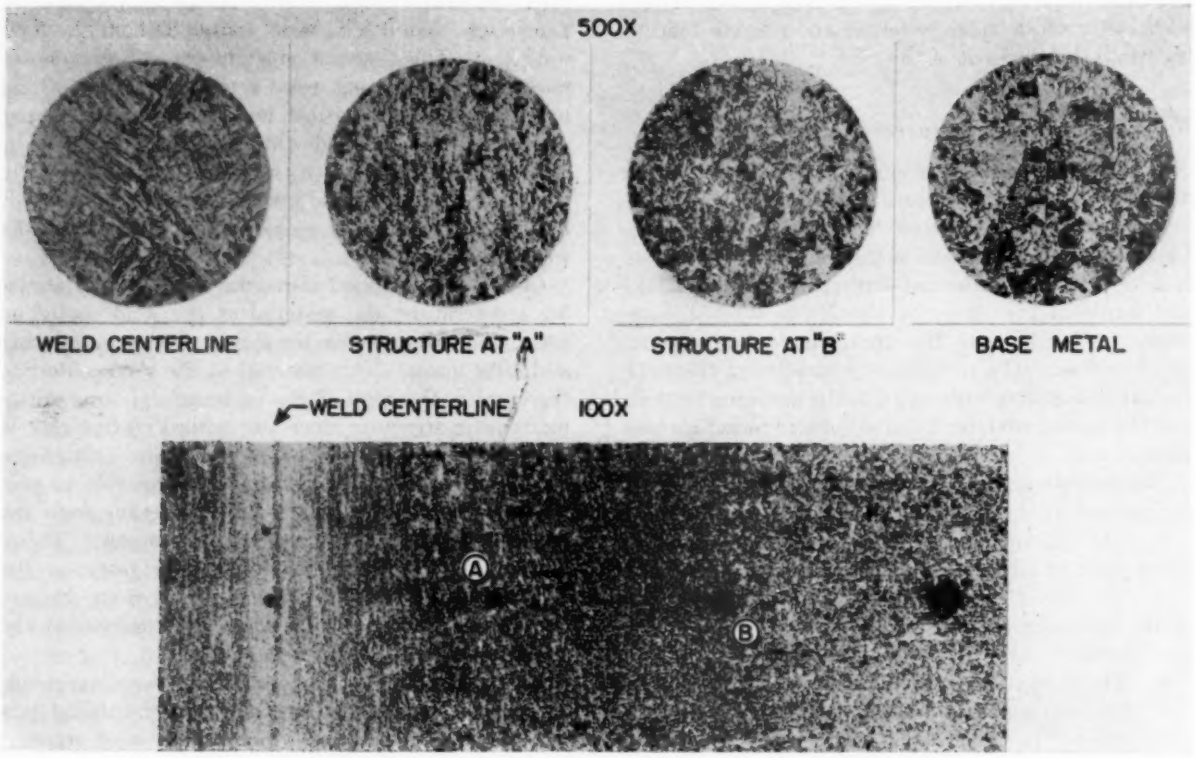


Fig. 18 Photomicrographs of flash weld in 4340 steel, weld centerline cooling rate 240° F/sec at 1300° F, as-welded

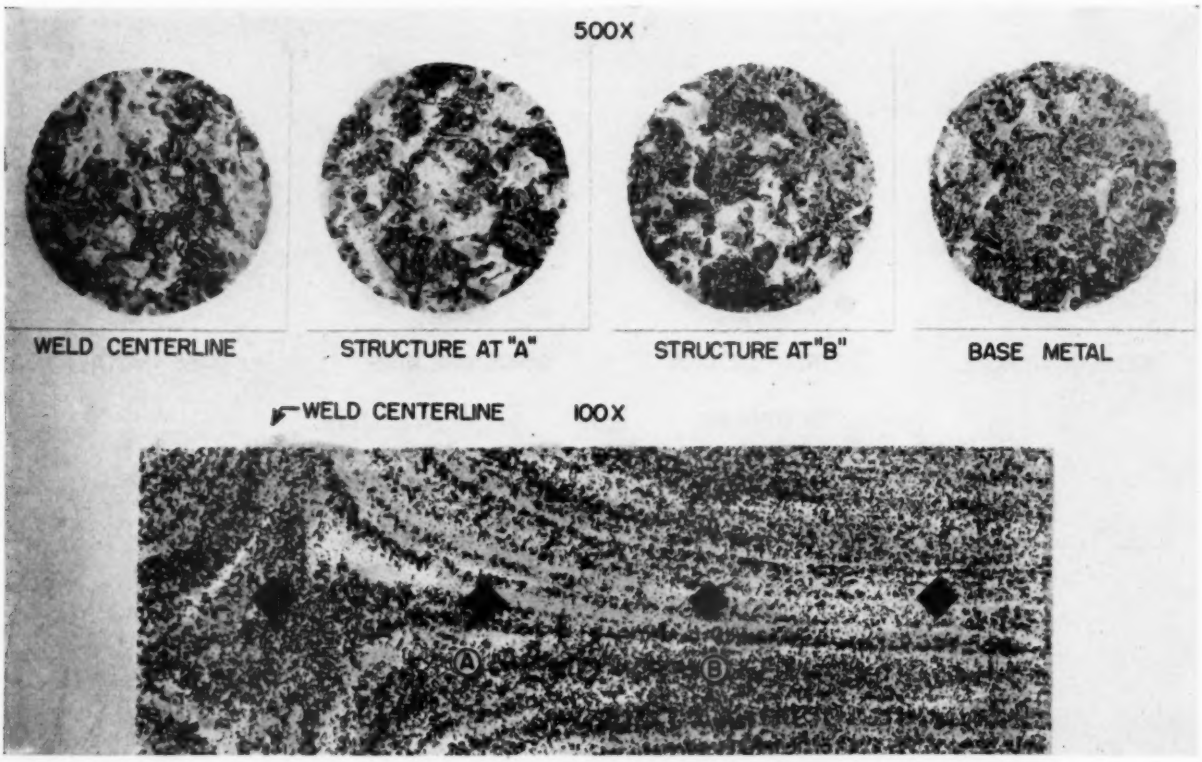


Fig. 19 Photomicrographs of flash weld in 4340 steel, weld centerline cooling rate 240° F/sec at 1300° F, normalized

It has been shown that equivalent cooling conditions will produce equivalent structures and properties in a given steel. Therefore, by locating a point on a Jominy bar of a particular steel which has the same cooling rate as found at the centerline of a flash weld in the same steel, it may be assumed that since the cooling rates are the same, the hardnesses must also be the same. For example, certain welds made during this investigation in AISI 4130 steel were found to experience a maximum cooling rate of 50° F/sec at 1300° F measured at the weld centerline. Reference to the literature, reveals that a cooling rate of 50° F/sec at 1300° F is also found at a distance of 0.4 in. from the water-quenched end of a Jominy bar. Referring to the Hardenability Band for 4130 H steel, the maximum expected hardness at a distance of 0.4 in. from the water-quenched end of a Jominy bar in 4130 H steel is found to be VPN 458 (46 Rc). This same hardness should be found at the weld line in a flash weld made in such a way as to produce a cooling rate of 50° F/sec at 1300° F. The actual measured hardness in welds made under these conditions was found to average VPN 540 (52 Rc), a value 6 Rockwell points higher than the predicted value.

A comparison of the observed and calculated hardness values at the weld centerline may be made by inspection of Table 5, columns 3 and 4. It may be seen that the observed hardness values are always equal to or greater than the calculated hardness values obtained by the above technique. This discrepancy may be due to one of two sources:

1. The cooling rate at 1300° F may not be the best means of relating the cooling conditions between the weld and the Jominy bar. Originally it was planned to select the cooling rate at an appropriate temperature range where the steel in question was most significantly affected, but at the present time no accurate data on the cooling rates at 1000 and 900° F is available in the range of Jominy distances involved. The cooling rates measured in flash welding correspond to those found at distances of 0.4 in. and less from the water-quenched end of a Jominy bar, and in the range from 0.0 to 0.5 in. from the water-quenched end the available data on Jominy bar cooling rates at 1000 and 900° F are unsatisfactory. Therefore, the cooling rate at 1300° F was taken as a working approximation for relating weld and Jominy bar data.

Table 5—Results of Hardness Traverses—Welds Prepared at Predetermined Cooling Rates

Centerline cooling rate, °F/sec at 1300° F	*Thickness, in.*	*Measured hardness at weld centerline, Rc*	*Predicted hardness at weld centerline, Rc*
	Material—AISI 4130		
260	3/8	54	54
240	1/4	56	53
85	3/8	54	50
50	3/8	52	46
	Material—AISI 4340		
260	3/8	60	60
240	1/4	61	60
85	3/8	62	60
50	3/8	60	60

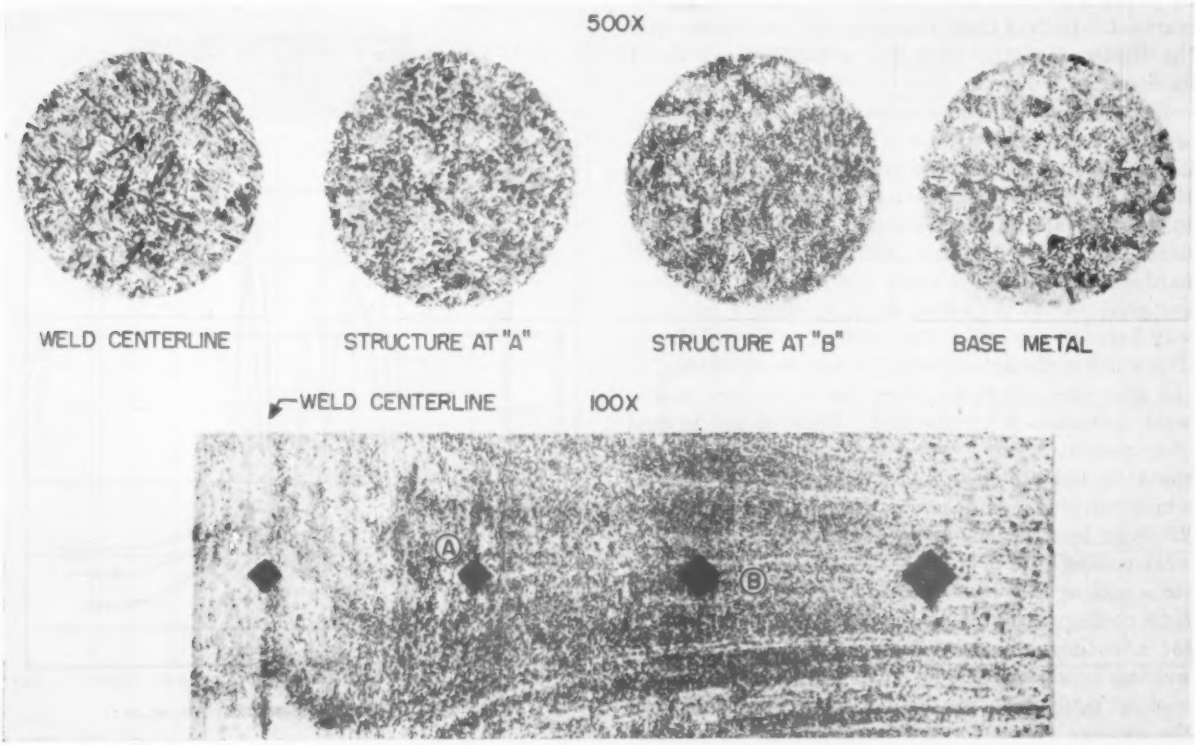


Fig. 20 Photomicrographs of flash weld in 4340 steel, weld centerline cooling rate 85° F/sec at 1300° F, as-welded

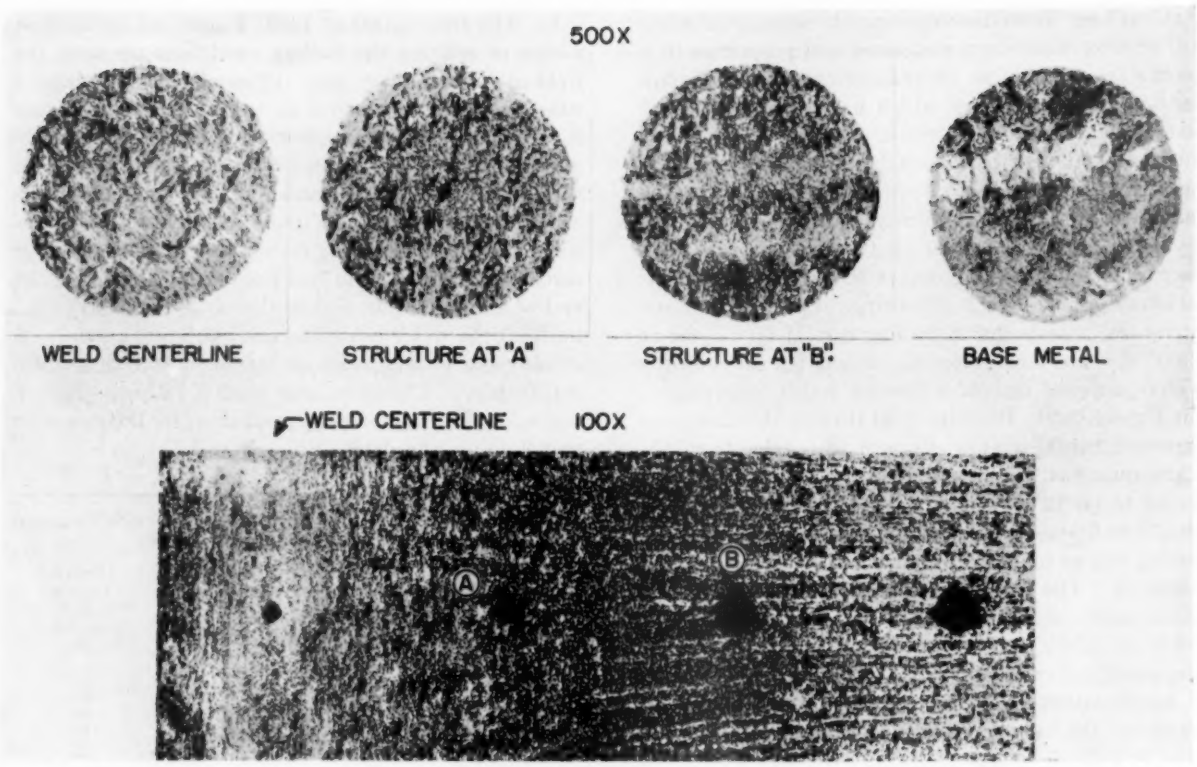


Fig. 21 Photomicrographs of flash weld in 4340 steel, weld centerline cooling rate 50° F/sec at 1300° F, as-welded

2. The mechanical working action produced in the material at the weld line by the upsetting action may cause a certain amount of increase in the hardness, both by producing a finer grain size and by cold working the material. Both of these sources would tend to increase the hardness at the weld line above the calculated hardness.

Figures 22 to 25 are hardness traverses of as-welded samples performed with a Vickers Hardness tester, using a pyramidal diamond indenter and a 10-kg load. Hardness indentations were made at intervals of 0.020 in. starting at the weld line and continuing outward until the unaffected base metal was reached. All hardness traverses were made in a longitudinal section perpendicular to the rolled surfaces, along a line midway between the two rolled surfaces of the bar stock. The width of the heat-affected zone is clearly evident in the alloy steels from the sharp rise in hardness as the weld centerline is approached. Each of the several plots presents hardness traverses for welds in the 4340, the 4130 and the 1020 grades, made under conditions which provide the same cooling rate at 1300° F. Figure 22 shows hardness traverses for the three steels with a weld cooling rate of 240° F/sec at 1300° F; Fig. 23, for a cooling rate of 260° F/sec at 1300° F; Fig. 24, for a cooling rate of 85° F/sec at 1300° F; and Fig. 25 for a cooling rate of 50° F/sec at 1300° F. The welding conditions employed in obtaining the above cooling rates differed slightly from steel to steel; the average values for the welding variables used in each case being listed in Table 6.

Reference to Figs. 22–25 reveals that the 4340 steel always exhibits the highest hardness at the weld line, the 1020, the lowest, and the 4130 an intermediate

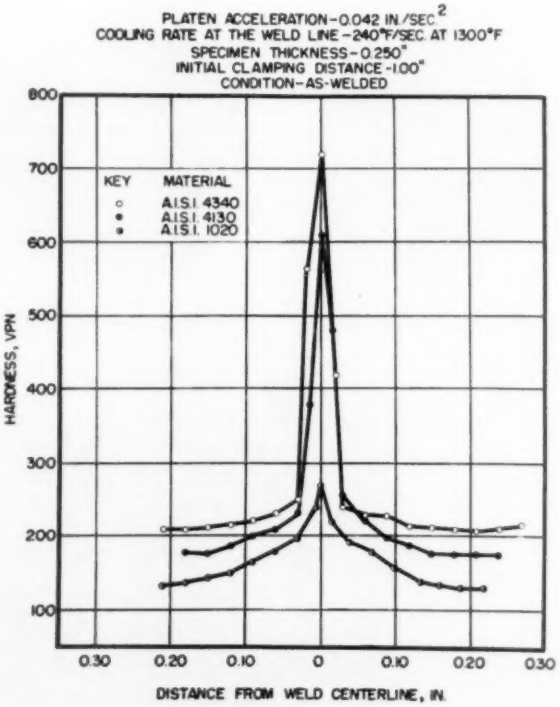


Fig. 22 Hardness traverses for typical flash welds—weld centerline cooling rate 240° F/sec at 1300° F, as-welded

Table 6—Welding Conditions Employed in Preparing Specimens for Hardness Traverses

Platen acceleration—0.042 ips²

Steel	Thickness, in.	Initial clamping distance, in.	Total burn-off, in.	Total upset distance, in.	Final clamping distance, in.	1300° F cooling rate at weld centerline, ° F/sec	Figure Nos. As-welded condition	Figure Nos. Normalized condition
1020	1/4	1.00	0.51	0.22	0.27	240	23	27
4130	1/4	1.00	0.52	0.21	0.27	240	23	27
4340	1/4	1.00	0.54	0.19	0.27	240	23	27
1020	3/8	1.00	0.49	0.24	0.27	260	24	28
4130	3/8	1.00	0.57	0.16	0.27	260	24	28
4340	3/8	1.00	0.58	0.15	0.27	260	24	28
1020	3/8	1.50	0.56	0.27	0.67	85	25	29
4130	3/8	1.50	0.67	0.16	0.67	85	25	29
4340	3/8	1.50	0.66	0.17	0.67	85	25	29
1020	3/8	2.00	0.52	0.22	1.26	50	26	30
4130	3/8	2.00	0.58	0.16	1.26	50	26	30
4340	3/8	2.00	0.59	0.15	1.26	50	26	30

Normalizing temperatures: AISI 1020–1655° F, AISI 4130–1625° F, AISI 4340–1575° F (20 min at temperature—air cooled on refractory brick).

hardness level. This reflects the fact that the 4340 has the greatest hardenability, and therefore exhibits a greater proportion of martensite at the weld line for a given cooling rate. In addition, since the hardness of martensite is greater the higher the carbon content of the austenite from which it forms, the 4340 having the highest carbon content, forms the hardest martensite. On the other hand, the 1020 steel has so little hardenability that no appreciable martensite is formed by the cooling rates obtained in this investigation and therefore shows only a slight increase in hardness at the weld line. The slight increase in hardness at the weld line in the 1020 steel may arise from three sources:

1. The production of more finely laminated pearlite, and suppression of the proeutectoid ferrite due to the comparatively rapid cooling rate.
2. A refinement in the grain size at the weld line due to the fact that the temperature at the weld line is only slightly above the A_3 temperature.
3. Work hardening of the material at the weld line by the forging action during the latter stages of upset.

Comparing Figs. 23, 24 and 25, it is of interest to note that welds made with the 260° F/sec cooling rate (Fig. 23) have the widest heat-affected zone in both the 4130 and 4340 grades. This effect, previously discussed in the metallography, has been attributed to the reduc-

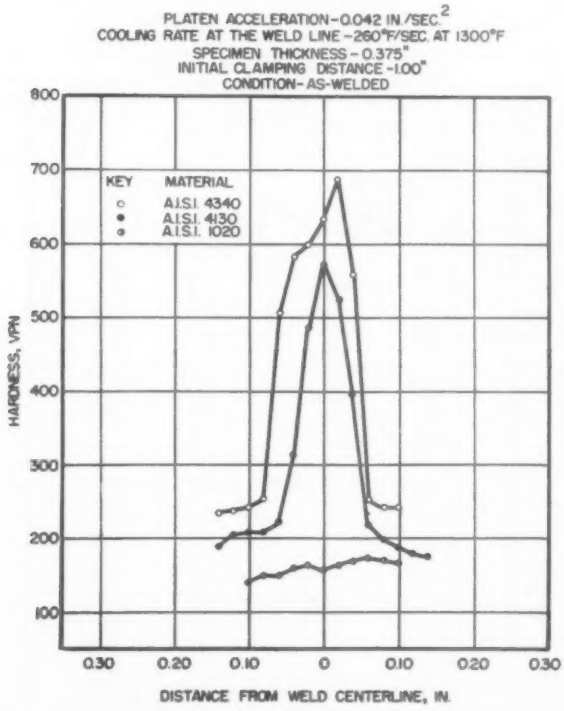


Fig. 23 Hardness traverses for typical flash welds—weld centerline cooling rate 260° F/sec at 1300° F, as-welded

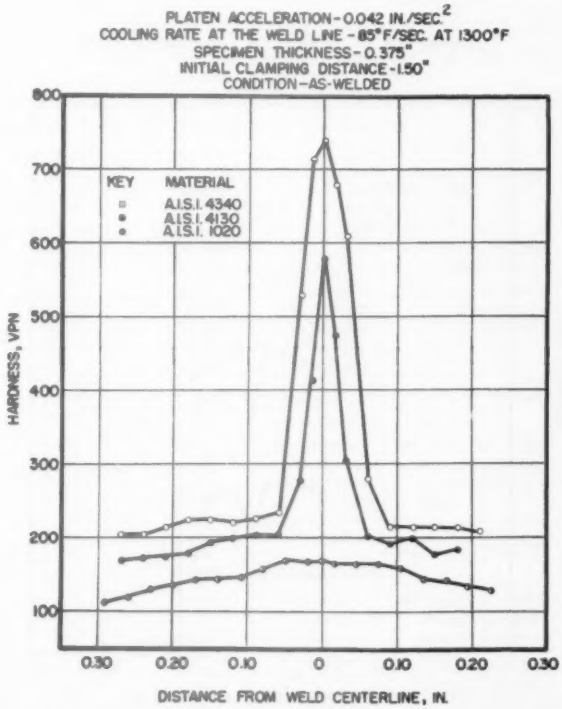


Fig. 24 Hardness traverses for typical flash welds—weld centerline cooling rate 85° F/sec at 1300° F, as-welded

tion in the upset action resulting from the greater high-temperature strength in the alloy steels. Comparison of Figs. 22 and 23, supports this theory, since the data in Fig. 22 were obtained from 0.250- x 2.00-in. specimens, using nearly the same welding conditions as were employed in Fig. 23. It is clearly evident that the increased unit upset force available by virtue of the smaller section size made more extensive upsetting action possible, and reduced the width of the heat-affected zone. It is of interest to note that with the 0.250- x 2.00-in. specimen size, hardening occurs at the weld centerline even in the 1020 steel. This effect may be seen by comparison of Figs. 22 and 23. It will be seen that the centerline hardness of the welds in 0.375- x 2.00-in. 1020 steel shows no appreciable change as compared with that of the parent material. On the other hand, in the 0.250- x 2.00-in. specimen (Fig. 22) of 1020 steel, the hardness at the weld centerline increases to VPN 270 as compared with VPN 120 for the parent material. The increase in hardness in this case is attributed to work hardening since with the smaller specimen area, the unit stress during upset was higher. This would permit forging to continue during upset after the temperature at the weld line had dropped below the recrystallization temperature. If this were the case, cold working would increase the hardness and account for the effect observed.

Figures 26–29 show the results of hardness traverses performed on specimens normalized after welding. The welding conditions and the normalizing temperatures may be found by reference to Table 6. Each plot contains data from welds made with conditions producing the same weld cooling rate in 4340, 4130 and 1020 steel specimens. It is of interest to note that after normalizing a pronounced dip is present in the hardness at the weld centerline in the alloy grades. The reason for the lower hardness at the weld line is not thoroughly

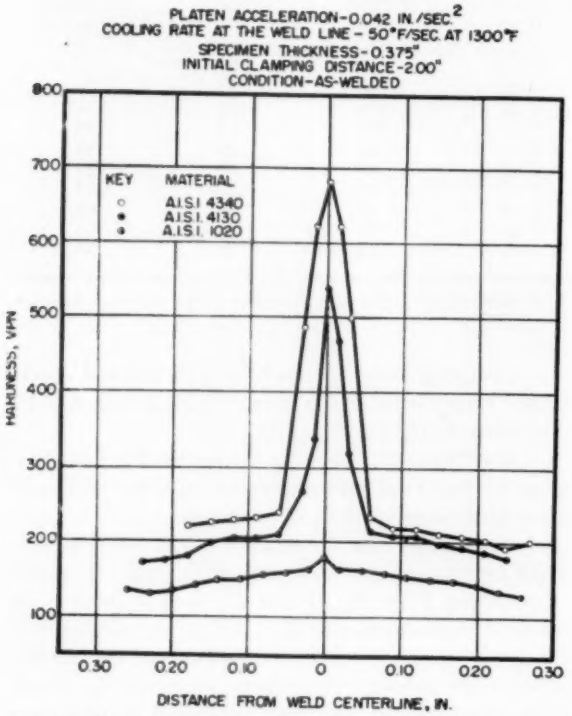


Fig. 25 Hardness traverses for typical flash welds—weld centerline cooling rate 50° F/sec at 1300° F, as-welded

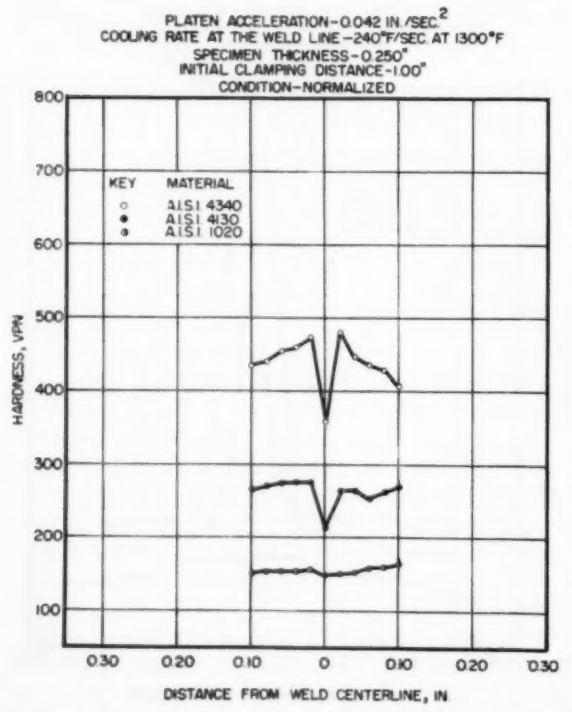


Fig. 26 Hardness traverses for typical flash welds—weld centerline cooling rate 240° F/sec at 1300° F, normalized

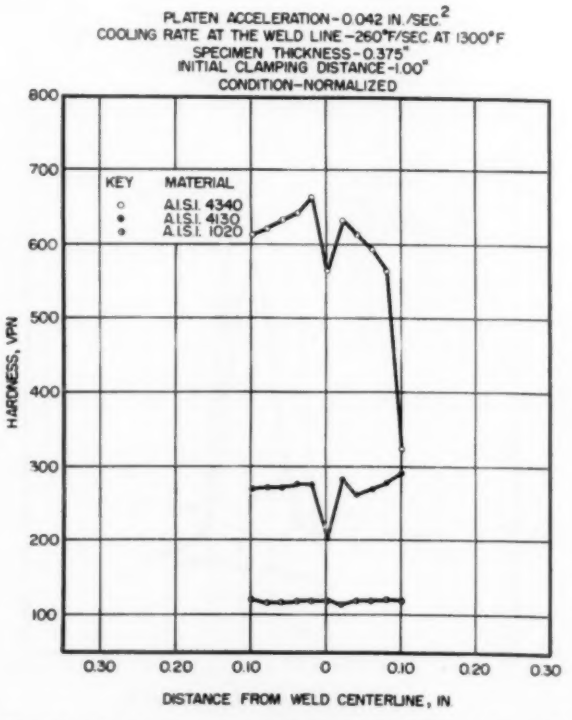


Fig. 27 Hardness traverses for typical flash welds—weld centerline cooling rate 260° F/sec at 1300° F, normalized

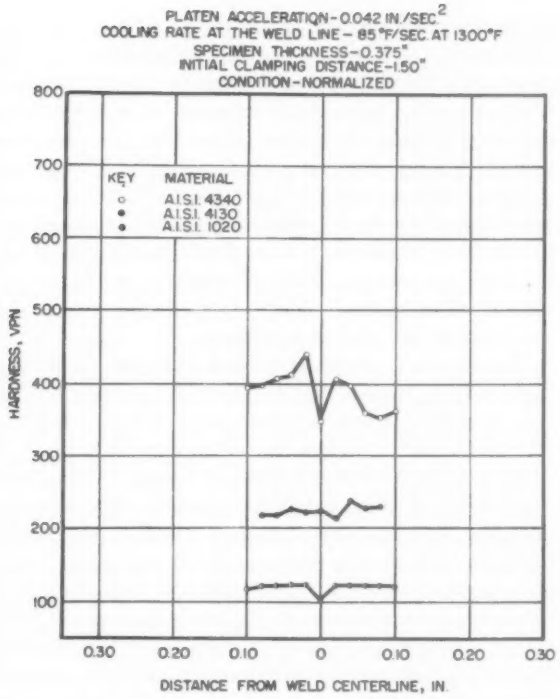


Fig. 28 Hardness traverses for typical flash welds—weld centerline cooling rate 85° F/sec at 1300° F, normalized

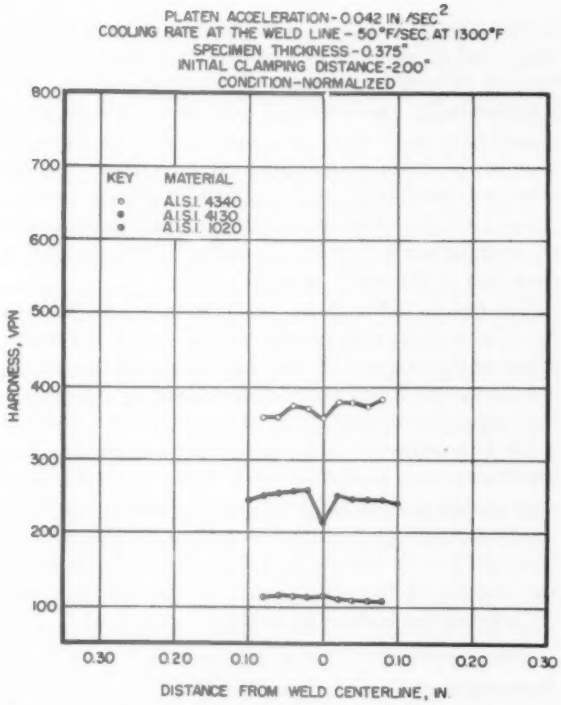


Fig. 29 Hardness traverses for typical flash welds—weld centerline cooling rate 50° F/sec at 1300° F, normalized

understood at this time, but it may be due to a slight amount of decarburization. Only one of the welds made in the 1020 steel exhibited this dip, possibly because of the relatively low initial carbon content, which would make the effect less noticeable. One sample apparently experienced an abnormally fast cooling rate during normalizing, see the 4340 weld in Fig. 27, since the observed hardness values are considerably higher than others of the same type.

Results of Tensile Tests

Table 7 lists the conditions employed in making each of the flash welds used in preparing tensile specimens. Four sets of welding conditions, producing four different weld cooling rates were utilized with each of the three

Table 7—Welding Conditions Employed in Preparing Specimens for Tensile Testing

Platen acceleration —0.042 ips²

Weld No.	*Steel*	*Original thickness, in.*	*Initial clamping distance, in.*	*Total burn-off, in.*	*Total upset distance, in.*	*Final clamping distance, in.*	*1300° F cooling rate at weld centerline, ° F/sec*	*Condition*	*Normalizing conditions*
1	1020	1/4	1.00	0.52	0.21	0.27	240	As-welded	20 min at 1655° F—air cooled on refractory brick
2	1020	1/4	1.00	0.53	0.20	0.27	240	Normalized	
3	1020	3/8	1.00	0.52	0.21	0.27	260	As-welded	
4	1020	3/8	1.00	0.56	0.17	0.27	260	Normalized	
5	1020	3/8	1.50	0.57	0.26	0.67	85	As-welded	
6	1020	3/8	1.50	0.57	0.26	0.67	85	Normalized	
7	1020	3/8	2.00	0.51	0.23	1.26	50	As-welded	
8	1020	3/8	2.00	0.52	0.22	1.26	50	Normalized	
9	4130	1/4	1.00	0.50	0.23	0.27	240	As-welded	20 min at 1625° F—air cooled on refractory brick
10	4130	1/4	1.00	0.52	0.21	0.27	240	Normalized	
11	4130	3/8	1.00	0.57	0.16	0.27	260	As-welded	
12	4130	3/8	1.00	0.56	0.17	0.27	260	Normalized	
13	4130	3/8	1.50	0.66	0.17	0.67	85	As-welded	
14	4130	3/8	1.50	0.67	0.16	0.67	85	Normalized	
15	4130	3/8	2.00	0.58	0.16	1.26	50	As-welded	
16	4130	3/8	2.00	0.59	0.17	1.26	50	Normalized	
17	4340	1/4	1.00	0.52	0.21	0.27	240	As-welded	20 min at 1575° F—air cooled on refractory brick
18	4340	1/4	1.00	0.53	0.20	0.27	240	Normalized	
19	4340	3/8	1.00	0.55	0.18	0.27	260	As-welded	
20	4340	3/8	1.00	0.59	0.14	0.27	260	Normalized	
21	4340	3/8	1.50	0.64	0.19	0.67	85	As-welded	
22	4340	3/8	1.50	0.68	0.15	0.67	85	Normalized	
23	4340	3/8	2.00	0.59	0.15	1.26	50	As-welded	
24	4340	3/8	2.00	0.59	0.15	1.26	50	Normalized	

grades of steel studied. Two specimens were made in each steel at each set of welding conditions, making a total of 24 weld specimens. By slitting each specimen longitudinally, two identical test specimens were obtained from each weld, or a total of four specimens at each set of welding conditions in each steel. As has been previously discussed, each specimen was surface-ground to size and notched with a grinding wheel dressed to produce a notch of 1/4 in. radius, 0.085 in. deep, at each end of the weld centerline.

The results of the tensile tests are tabulated in Table 8. The cooling rate experienced in each case will be found in the extreme left-hand column, and the welding conditions employed may be determined by reference to the appropriate weld number in Table 7. Two as-welded specimens and two welded-and-normalized specimens were tested for each value of weld cooling rate studied in each grade of steel. In addition to the tensile strength and elongation data, a code number has been assigned describing the nature of each fracture. A key explaining the significance of this code has been included at the bottom of Table 8.

Summary of Tensile Test Results

AISI 1020 As-welded. The welds made with conditions producing cooling rates in excess of 240° F/sec all failed outside the reduced section when tested in the as-welded condition. Since hardness traverses revealed a slight increase in hardness at the weld zone in these samples, and since all other weld specimens failed at the reduced section, it was concluded that the increase in hardness accompanying the fast cooling rates was sufficient to compensate for the reduced area at the notch, thus shifting the failure to the parent material.

All as-welded specimens except one in the 1020 steel showed a ductile, shear-type failure, the one exception being a sample exhibiting a "flat spot." The tensile strength values ranged from 81,300 to 68,400 psi, with the 0.250-in. specimens exhibiting a tensile strength approximately 10,000 psi greater than those found for the 0.375-in. specimens. This discrepency probably results from the greater degree of restraint imposed by the notch in the thicker specimens.

The ductility of the as-welded 1020 specimens was high, ranging from 35 to 71% in a 0.37-in. gage length. No significant trend was observed between cooling rate and ductility in the as-welded condition.

AISI 1020 Normalized After Welding. After being normalized, all welds exhibited approximately the same ductility, 53–59%, and all showed a ductile, shear-type fracture. The tensile strength of the normalized samples ranged from 61,800 to 72,100 psi, with the higher values again obtained for the 0.250-in. specimens. The above strengths compare favorably with the 60,000–70,000 psi observed for the parent plate after normalizing in the same manner.

AISI 4130 As-welded. Five of the as-welded specimens failed outside of the weld zone and showed a ductile fracture with 41–58% elongation. The balance of the welds failed at the weld, and showed lower strength, low ductility and a completely brittle fracture. No consistent correlation was observed between weld strength and weld cooling rate.

Table 8—Results of Tensile Tests of Welded Specimens

Cooling rate, ° F/sec	*Original specimen thickness, in.*	*As-welded specimens*				*Normalized specimens*			
		Weld No.	*Tensile strength, psi*	*Elongation in 0.37 in., %*	*Failure type*	*Weld No.*	*Tensile strength, psi*	*Elongation in 0.37 in., %*	*Failure type**
				Material—AISI 1020					
260	3/8	3	70,600	66	5†	4	64,200	59	5
260	3/8	3	70,700	71	5†	4	64,200	58	5
240	1/4	1	80,500	58	5†	2	71,600	53	5
240	1/4	1	81,300	66	5†	2	72,100	53	5
85	3/8	5	70,400	48	5	6	61,800	53	5
85	3/8	5	70,800	42	3‡	6	61,900	56	5
50	3/8	7	73,000	56	5	8	65,500	54	5
50	3/8	7	68,400	35	5	8	65,900	56	5
				Material—AISI 4130					
260	3/8	11	63,200	2	1	12	128,000	15	2
260	3/8	11	100,700	41	5†	12	115,000	17	2
240	1/4	9	99,300	43	5†	10	130,500	4	5
240	1/4	9	97,600	42	5†	10	129,100	10	5
85	3/8	13	99,400	58	5†	14	120,800	39	3
85	3/8	13	78,900	6	1	14	118,200	27	3
50	3/8	15	101,200	43	5†	16	123,000	30	4
50	3/8	15	98,200	15	1	16	122,100	16	5
				Material—AISI 4340					
260	3/8	19	58,900	0	1	20	190,500	9	1
260	3/8	19	44,600	3	1	20	200,500	12	2
240	1/4	17	72,700	0	1	18	254,000	6	1
240	1/4	17	85,000	1	1	18	210,000	4	1
85	3/8	21	83,700	1	1	22	191,000	13	2
85	3/8	21	112,600	10	1	22	159,200	4	1
50	3/8	23	107,800	8	1	24	187,400	11	1
50	3/8	23	76,100	3	1	24	177,700	15	2

* Failure type: 1, full brittle; 2, 3/4 brittle; 3, half brittle-half shear; 4, 3/4 shear; 5, full shear.
† Failed outside of weld zone.
‡ Flat spot.

AISI 4130 Welded and Normalized. After normalizing, the weld strengths were consistently increased to 115,000 psi or more, but the ductility varied erratically from 4 to 39%. The high values of tensile strength and erratic ductilities may be attributed to the fairly rapid cooling rate obtained by normalizing the specimens individually. It would appear that in the future, more significant results could be obtained by tempering after normalizing at 1100° F.

AISI 4340 As-welded. All welds failed in the notched region, and showed low ductility and low erratic tensile strengths. This would be expected from the presence of martensite and the high hardness observed in the as-welded specimens of 4340. There appears to be a slight trend toward higher ductility with the slower cooling rates, as might be expected.

AISI 4340 Welded and Normalized. After normalizing, the tensile strengths were all found to be above 159,000 psi, but the large spread in the observed strengths, 159,200–254,000 psi, again reflect the presence of martensitic structures resulting from the relatively fast air cooling of the normalizing treatment. In future work, the normalizing treatment will be followed by a suitable tempering treatment to improve the ductility of the 4340 welds.

SUMMARY AND CONCLUSIONS

Weld centerline cooling rates were determined as functions of three welding variables, the rate of platen acceleration, the final clamping distance and the thickness of the material, for flash welds employing parabolic flashing patterns. Three rates of platen acceleration, 0.120, 0.042 and 0.0166 ips^2, were investigated, with a range of final clamping distances of 0.3 to 1.2 in., for rectangular bar material of 0.250 and 0.375 in. thickness.

1. The cooling rates experienced at the centerline of flash welds were found to range from 365° F/sec to 40° F/sec at 1300° F.

2. The weld cooling rate was found to be a function of: (*a*) the final clamping distance, (*b*) the platen acceleration and (*c*) the section thickness.

3. For the range of final clamping distance 0.3–1.2 in., it was found that decreasing the final clamping distance increased the weld cooling rate.

4. The platen acceleration, previously shown to influence the temperature gradient established during flashing,[4, 5] was shown to affect the weld cooling rate, particularly with final clamping distances greater than 0.5 in. In general, faster rates of platen acceleration were shown to produce faster weld cooling rates.

5. The cooling rate in flash welds was found to be increased slightly by an increase in the section thickness.

6. Curves showing the effect of final clamping distance, platen acceleration and section thickness on the weld cooling rate were presented and discussed.

7. Photomicrographs of typical flash welds in AISI 1020, 4130 and 4340 steels were presented and discussed.

8. Hardness traverses, taken from typical welds in AISI 1020, 4130 and 4340 were presented and discussed.

9. Based upon evidence obtained from photomicrographs and hardness traverses, and the results of the thermal studies, it was found impractical to attempt to avoid the formation of maternsite in either the 4130 or 4340 by selection of welding variables. This results from the fact that both the 4130 and 4340 steels exhibit such a high hardenability that it is difficult to obtain cooling rates less rapid than the critical cooling rate for either of these steels in the section sizes studied.

10. The upset force requirements were found to be greater for the alloy steels, due to their greater high temperature strength.

11. Tensile strengths corresponding to 100% joint efficiency were readily obtained in the AISI 1020 steel as-welded.

12. Normalizing the AISI 1020 steel after welding caused a slight reduction in the strength, but provided more consistent values of ductility.

13. The as-welded tensile test in the 4130 and 4340 grades of steel gave erratic values of strength and ductility due to the presence of a brittle martensitic structure in the vicinity of the weld.

14. Normalizing improved the strength and ductility of the welds, but photomicrographs and hardness traverses revealed the presence of martensitic structures after the normalizing treatment given.

15. Slower cooling from the normalizing temperature, such as would be obtained with more massive assemblies would improve this situation, but a tempering operation would be advisable to improve the ductility of small assemblies.

ACKNOWLEDGMENTS

The authors wish to acknowledge the financial support provided this investigation by the Air Research and Development Command, Wright-Patterson Air Force Base, Ohio, under Contract No. AF18 (600)-71. This project was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with R. E. Bowman acting as project engineer.

They also wish to acknowledge the advice and suggestions received from the Flash Welding Subcommittee of the Welding Research Council.

References

1. Nippes, E. F., Savage, W. F., McCarthy, J. J., and Smith, S. S., "Temperature Distribution During Flash Welding of Steel," THE WELDING JOURNAL, 30 (12), Research Suppl., 585-s to 601-s (1951).

2. Nippes, E. F., Savage, W. F., Smith, S. S., McCarthy, J. J., and Grotke, G., "Temperature Distribution During Flash Welding of Steel—Part II," Ibid., 32 (3), Research Suppl., 113-s to 122-s (1953).

3. Curran, R. M., Patriarca, P., and Hess, W. F., "Optimum Flash Welding Conditions, the Importance of Temperature Measurements," Ibid., 27 (12), Research Suppl., 577-s to 592-s (1948).

4. Nippes, E. F., Savage, W. F., McCarthy, J. J., and Patriarca, P., "Optimum Flash Welding Conditions for Aluminum Alloys," Ibid., 29 (10), Research Suppl., 497-s to 511-s (1950).

5. Moyer, E. E., and Savage, W. F., "A New Method of Controlling Platen—Displacement vs. Time During Flash Welding," AIEE Conference Report for AIEE Welding Conference held in Detroit, Mich., April 1952.

Appendix

Welding Conditions Employed in Preparing Specimens for Cooling Rate Determination

AISI 1020 Steel—0.250- x 2.00-in. section; Approximate Burn-off—0.5 in.

Run No.	*Group*	*Initial clamping distance, in.*	*Total burn-off, in.*	*Total upset, in.*	*Platen travel, in.*	*Final clamping distance, in.*
			Platen acceleration—0.120 ips²			
1	A	1.00	0.59	0.17	0.76	0.24
2		1.00	0.56	0.18	0.74	0.26
3		1.00	0.53	0.21	0.74	0.26
4		1.00	0.57	0.19	0.76	0.24
5	B	1.20	0.58	0.27	0.85	0.35
6		1.20	0.54	0.28	0.82	0.38
7		1.20	0.53	0.25	0.78	0.42
8		1.20	0.60	0.24	0.84	0.36
9	C	1.50	0.51	0.31	0.82	0.68
10		1.50	0.50	0.31	0.81	0.69
11		1.50	0.52	0.29	0.81	0.69
12		1.50	0.52	0.29	0.81	0.69
			Platen acceleration—0.042 ips²			
13	D	1.20	0.58	0.32	0.90	0.30
14		1.20	0.53	0.31	0.84	0.36
15		1.20	0.53	0.31	0.84	0.36
16		1.20	0.56	0.32	0.88	0.32
17	E	1.50	0.44	0.36	0.80	0.70
18		1.50	0.49	0.35	0.84	0.66
19		1.50	0.46	0.36	0.82	0.68
20		1.50	0.46	0.35	0.81	0.69
21	F	2.00	0.46	0.34	0.80	1.20
22		2.00	0.46	0.34	0.80	1.20
23		2.00	0.46	0.33	0.79	1.21
24		2.00	0.42	0.34	0.76	1.24
			Platen acceleration—0.0166 ips²			
25	G	1.20	0.59	0.33	0.92	0.28
26		1.20	0.53	0.33	0.86	0.34
27		1.20	0.54	0.32	0.86	0.34
28		1.20	0.54	0.33	0.87	0.33
29	H	1.50	0.51	0.37	0.88	0.62
30		1.50	0.45	0.37	0.82	0.68
31		1.50	0.48	0.37	0.85	0.65
32		1.50	0.45	0.37	0.82	0.68
33	I	2.00	0.52	0.33	0.85	1.15
34		2.00	0.44	0.35	0.79	1.21
35		2.00	0.50	0.33	0.83	1.17
36		2.00	0.51	0.35	0.86	1.14
			AISI 1020 Steel—0.375- x 2.00-in. section; Platen Acceleration—0.042 ips² Approximate burn-off—0.5 in.			
37	J	1.20	0.60	0.22	0.82	0.38
38		1.20	0.59	0.23	0.82	0.38
39		1.20	0.59	0.24	0.83	0.37
40		1.20	0.57	0.23	0.80	0.40
41	K	1.50	0.55	0.25	0.80	0.70
42		1.50	0.55	0.27	0.82	0.68
43		1.50	0.55	0.26	0.81	0.69
44		1.50	0.50	0.24	0.74	0.76
45	L	2.00	0.51	0.26	0.77	1.23
46		2.00	0.54	0.25	0.79	1.21
47		2.00	0.56	0.25	0.81	1.19
48		2.00	0.59	0.23	0.82	1.18
			Approximate burn-off—0.7 in.			
49	M	1.20	0.72	0.17	0.89	0.31
50		1.20	0.72	0.12	0.84	0.36
51		1.20	0.82	0.17	0.95	0.25
52		1.20	0.75	0.15	0.90	0.30
53	N	1.50	0.68	0.17	0.85	0.65
54		1.50	0.73	0.16	0.89	0.61
55		1.50	0.74	0.17	0.91	0.59
56		1.50	0.72	0.17	0.89	0.61
57	O	2.00	0.76	0.15	0.91	1.09
58		2.00	0.78	0.14	0.92	1.08
59		2.00	0.74	0.17	0.91	1.09

NOTE: Since the upset force was consistently within the limits of 23.5–24.5 kip, it has not been included in the above tabulation.

The Significance of the Tension Test for Spot Welds

A spot weld can support in pure tension a load several times that normally measured by the conventional tension test

by E. R. Funk

INTRODUCTION

A TENSILE-SHEAR test has been the most common test for spot weld quality. However, it has been recognized that such a test is not completely discriminating and that it is not, by itself, a satisfactory criteria for spot weld quality. This has been evident in one case where spots of satisfactory tensile-shear strength have been made which broke during subsequent shop handling. In this case, a tension test of a spot was performed and gave very low values. A change in welding settings gave shear values still meeting the required specifications and also produced spots of much higher tensile strength. No fracture during subsequent fabricating was found when the improved settings were used.

This example is related to emphasize the desirability of a more discriminating test for spot weld quality than the tensile-shear test alone. A tension test is often used, and rightly so. However, whenever a tension test for spot weld is mentioned, a question arises regarding the interpretation of the results and particularly the meaning of the tension-shear ratio.

Admittedly the commonly used jigs for testing the "crossed-strip" single-spot weld in tension do not give uniform tension loading in the weld. Pure tension requires that no bending whatever of the strips be permitted. This condition can be met only by an infinitely stiff sheet. In some preliminary experiments this stiffness condition was approximated by bonding spot-welded titanium sheets to 1-in. aluminum blocks by epon resin. When these spots were pulled in tension the load reached 1600 lb at which point the epon resin fractured. In the "crossed-strip" tension tests similar spot welds fractured at loads in the order of 300 lb. This demonstrated conclusively that a spot can support in pure tension a load several times that normally measured by the conventional tension tests.

E. R. Funk is Engineering Consultant, Technical Service Department, Goodyear Aircraft Corp., Akron, Ohio.

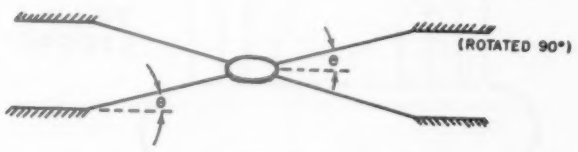


Fig. 1 Schematic diagram of conditions during crossed-strip tension test

DISTRIBUTION OF THE VERTICAL LOAD

The conventional "crossed-strip" tension test allows the strips to bow between the clamping points. This condition is shown schematically in Fig. 1. Since the strips can support no moment over their length, the load in the strips must be tensile. The load condition at the edge of the nugget is that shown in Fig. 2 where $V = R \sin \theta$ and $H = R \cos \theta$. V is the vertical component acting on the nugget which tends to tear it apart in tension. A sketch of the nugget loading at the beginning of the tensile test is shown in Fig. 3. The total applied load is $2V$.

Consider a nugget cross section with the applied vertical loads V. The total load in the tensile test is, as pointed out previously, $2V$. As the load is applied, V increases until at the edge the yield point is reached. The stress distribution at the edge of the nugget is then that shown schematically in Fig. 4.

The above analysis is a simplified condition and neg-

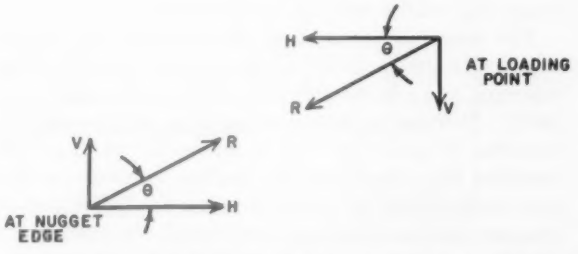


Fig. 2 Load conditions on nugget and sheet during tension test

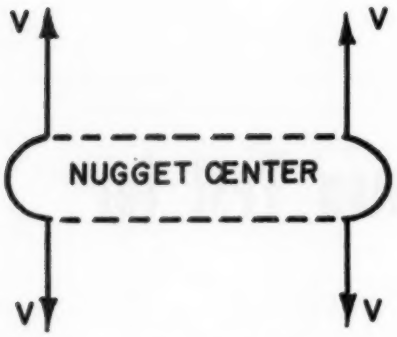


Fig. 3 Applied vertical load on weld nugget

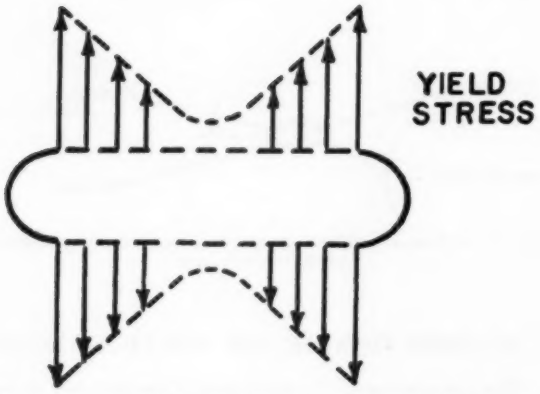


Fig. 4 Stress distribution on nugget under the load of Fig. 3 at yield strength

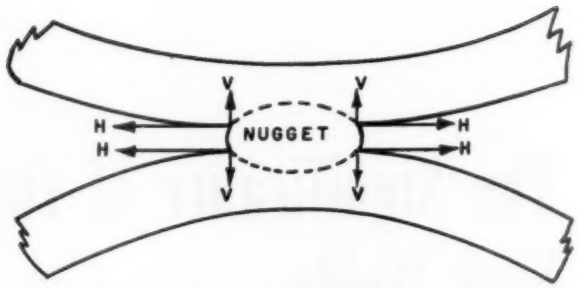


Fig. 5 Schematic diagram of the loading on a weld nugget in tension

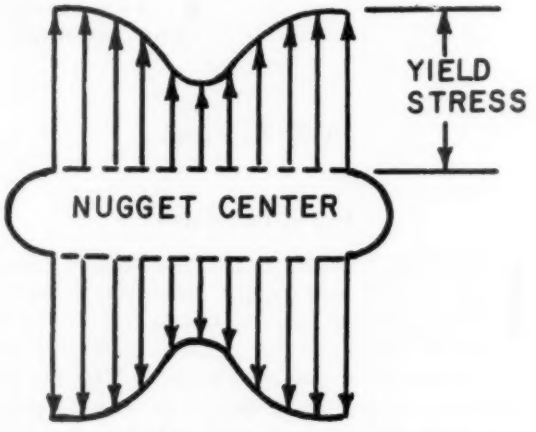


Fig. 6 Stress distribution on nugget after yielding

lects the important effects of the radial tensile loads on the nugget.

A radial tensile loading on the spot-weld nugget arises from the horizontal component of the reaction at the edge of the spot weld as shown in Fig. 2. Figure 5 shows this loading on the nugget in a tension test. The magnitude of the horizontal loading depends on the angle θ, and therefore is related to the specimen stiffness.

An additional radial tensile load on the nugget also exists due to a necking down of the nugget as required by plastic flow, i.e., as the nugget lengthens, the diameter must decrease to preserve equivalent volumes. The very short gage length (the distance between the sheets) means that the sheet material exerts a restraining influence on the nugget to keep it from necking down. This puts the sheet in compression and the nugget in radial tension in all directions.

The actual distribution of stress across the nugget depends on two factors; (1) the stiffness of the backing material, and (2) the ductility of the weld nugget material. Stiffness, of course, depends on section size and modulus of elasticity. It is interesting that a high modulus helps distribute the loading, so that stainless steel spots would be expected to have a higher tensile fracture load than titanium even though the yield points and fracture stresses may be roughly the same. Some preliminary data in the literature have shown this to be so and it should not be alarming to find stainless has a higher tension-shear ratio than titanium.

The part ductility plays in the distribution clearly is determined by the fact that high ductility means that a relatively large nugget area may be brought up to the yield stress. With a ductile weld the stress distribution may be that shown in Fig. 6. However, when the ductility is low, little yielding can occur to distribute the load before fracture at the edge occurs. Of course, when fracture starts, the severe notch at the base of the fracture promotes over-all separation due to the high stress concentration factor.

The value of the yield stress of the weld nugget is not that determined by the conventional yield test. The radial tension loads combine with the axial tension to give a condition of triaxial tension on any elemental volume of metal within the nugget. Material loaded in triaxial tensile stress has a higher yield stress than the material in axial tensile loading alone. Therefore it can be concluded that even when the nugget is subject to pure tension, a condition of triaxiality of stresses develops which results in a higher yield stress than the uniaxial yield stress.

CONCLUSIONS

In conclusion, it can be understood how a tension test can be used as a measure of the weld nugget ductil-

ity. At the same time, the pitfalls in such an arbitrary relationship have been highlighted. The large effect of geometry of the test strip and the modulus of elasticity have been pointed out. It is clear why tension results have such wide scatter and why so many anomalies are encountered in tension-shear ratios. Furthermore, a fixture cannot be designed that accurately duplicates in a large test specimen the stress distribution occurring at the edge of the spot-weld nugget during tension testing.

Fatigue Tests of Welded Beam Connections

by Otto Graf

ON JULY 5, 1935, the German Steel Structures Committee embarked on a series of fatigue tests of beam connections for bridges. Some of these tests have been reported. (See Klöppel, *Stahlbaukalender*, **1939**, 444–445; **1940**, 416–417; Graf, *Bauingenieur*, **19**, 530 (1938.) The remainder are reported herein.

TESTS ON THE SPECIMENS OF FIGS. 1 TO 6

The specimen in Fig. 1 (dimensions are in millimeters) was fillet welded. The outside flange fillets (fillet dimensions refer to throat) were welded first, then the inside flange fillets and finally the web fillets. In Fig. 2 the flanges were butt welded. The web was not welded. In Fig. 3 the flanges were butt welded as in Fig. 2 but the webs were fillet welded. In Fig. 4 the welds were the same as Fig. 3, but seats were welded under the beam. In Fig. 5 a strap, passing through a hole in the girder, was fillet welded to both beams. In addition the lower surface of the top flange as well as the web and bottom flange were fillet welded. In Fig. 6 the top flange was butt welded, but the lower flange and web were fillet welded.

Abstract of "Versuche über die Widerstandsfähigkeit von geschweissten Quertrageranschlüssen bei oftmals wiederholter Biegebelastung," published in *Berichte des Deutschen Ausschusses für Stahlbau*, Heft 17, 1–19 (1952). (Abstracted by Dr. G. E. Claussen.)

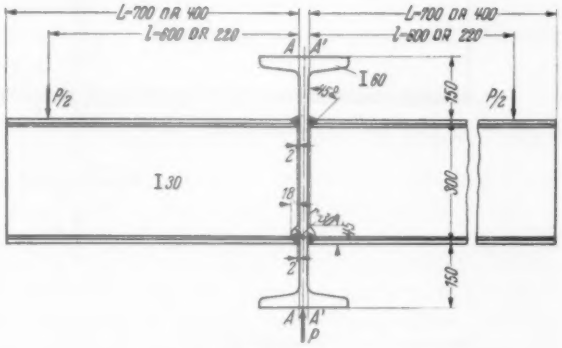


Figure 2

The girders and beams were made of mild steel which averaged 37,000–50,000 psi yield strength, 56,000–64,000 psi tensile strength. The I30 section had a cross-sectional area of 10.7 sq in. and a moment of inertia of 237 in.^{4}. The welding electrodes were GHH Pan (6020). They were used on d-c 100 amp for $^1/_8$ in., 180 amp for $^5/_{32}$ in. and 200 amp for $^3/_{16}$ in. In preliminary tests the loads were 35 in. from the girder. Smaller distances were used in the main tests to increase the shear on the welds. The loading was from zero to maximum at the rate of 210 cpm. The stress corresponding to zero load amounted to not over 1400 psi in the sections A-A or A′-A′. The endurance limit was the stress for one million cycles without failure.

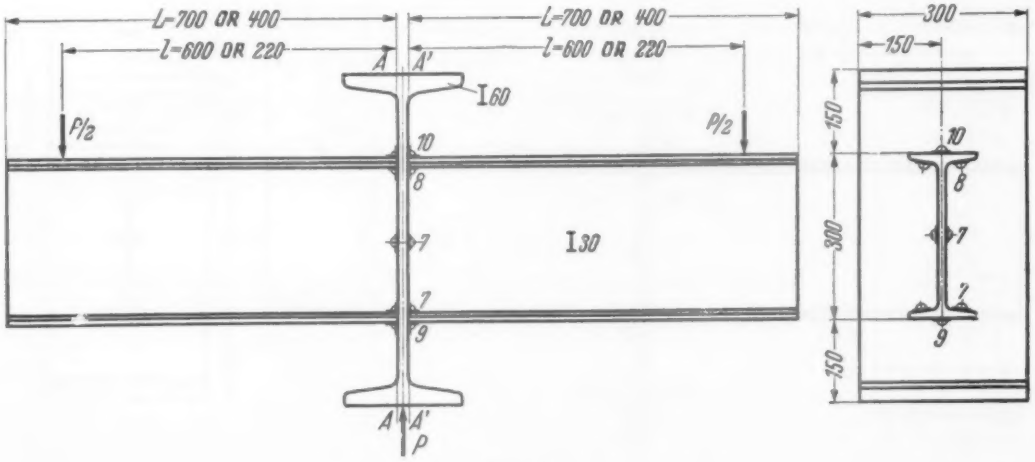


Figure 1

The endurance limit for the specimen in Fig. 1 was 14,200 psi for $l = 23^1/_2$ in. For $l = 8^5/_8$ in. the limit was a little higher. The bending stress rather than the shear stress was the determining factor. Fracture started at the top of the tension flange at the toe of the fillet. Cracks were found at the junction of flange with web under the load.

The limit for Fig. 2 was also 14,200 psi. Since the

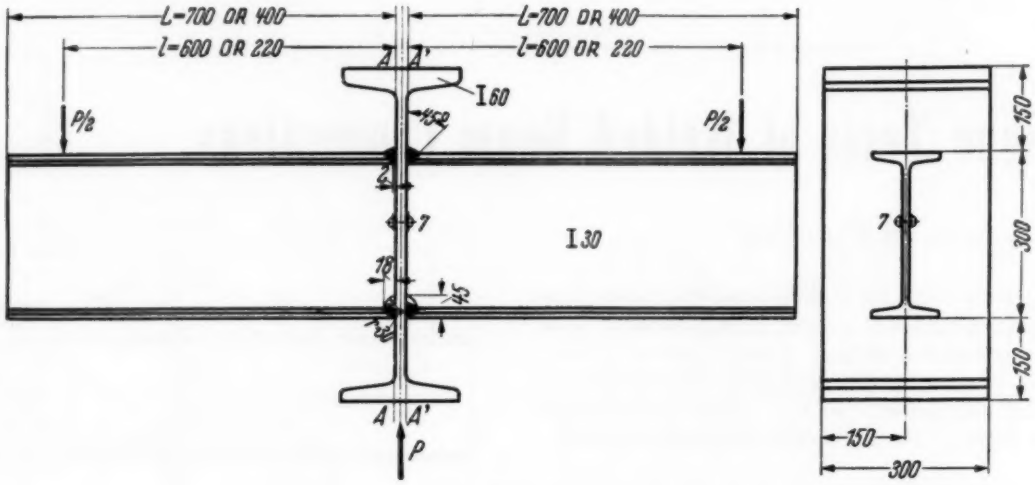


Figure 3

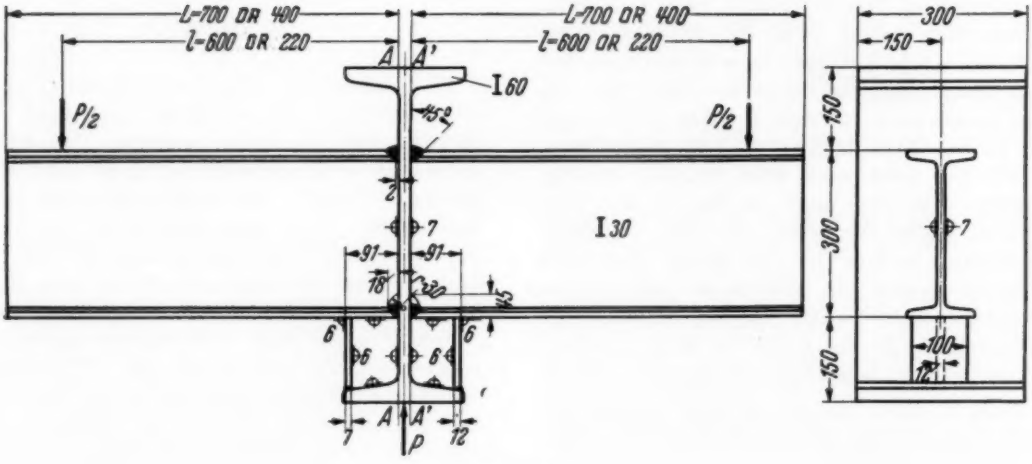


Figure 4

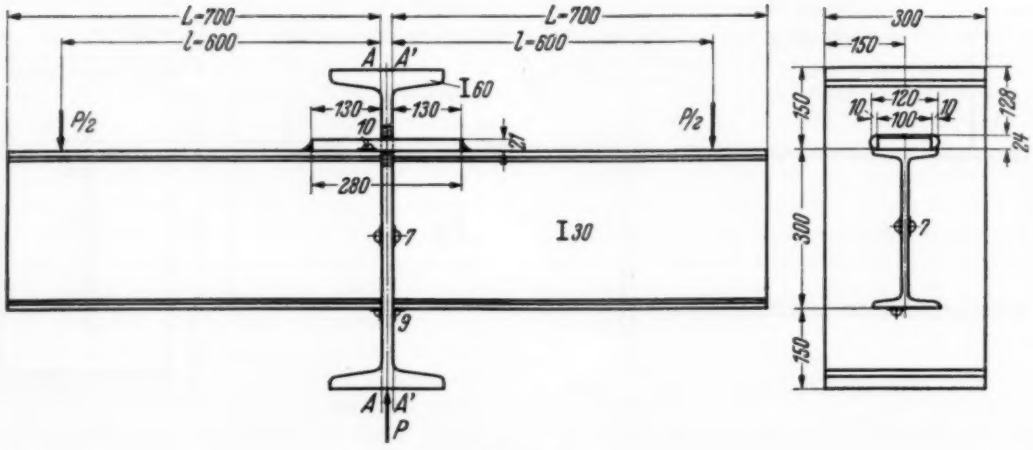


Figure 5

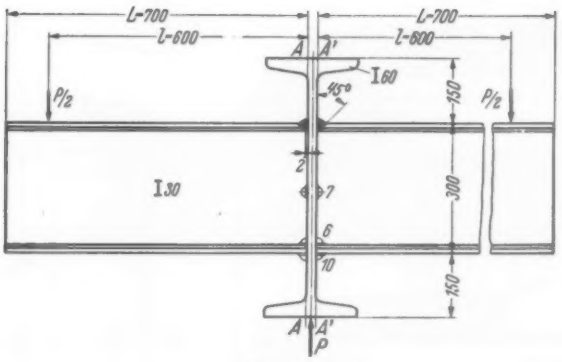


Figure 6

web was not welded the resultant fatigue limit made up of bending and shear was 16,100 psi. The limit for $l = 8^5/_8$ in. was a little lower. In one specimen fracture started at the junction of the butt weld with the tension flange. In the other three specimens cracks appeared first in the butt weld in the compression flange. Obviously the shrinkage stresses due to welding, together with the notches in the unground butt-weld surface have led to tensile fatigue failure in the compression zone of the specimen.

The endurance limit for the specimen in Fig. 3 was 17,800 psi. The surfaces of the butt welds of one specimen were smoothed with a rotary file. This specimen withstood 603,000 cycles before the first crack, compared with a specimen with as-deposited welds which withstood 265,600 cycles at the same stress (22,000 psi). Cracks appeared first in the butt weld in the compression flange in these specimens, final fracture occurring at the edge of the butt in the tension flange. In every specimen cracks started at small notches in the surface of the weld.

The specimen in Fig. 4 had a little higher endurance limit (20,000 psi) then the specimen in Fig. 3. For specimens with $l = 23^1/_2$ in. fracture started at the junction of the butt weld with the tension flange. With $l = 8^5/_8$ in. the first crack usually started at a fillet weld in the seat.

The specimen in Fig. 5 had an endurance limit of 17,100 psi. The through strap did not raise the fatigue strength because the side fillet welds were weak in fatigue. The specimen in Fig. 6 also had an endurance limit of 17,100 psi. The butt weld to the compression flange in Fig. 3 was a little better than the fillet weld in Fig. 6.

These tests show that it is desirable to butt weld the tension flange. Fillets are adequate for the compression flange, and thin, single-layer fillets are sufficient for the web. Additional tests on straps are described below.

TESTS ON THE SPECIMENS OF FIGS. 7 TO 9

Straps $13^3/_4$ in. long, 5 in. wide and $^3/_4$ in. thick were butt welded to the tension and compression flanges in Fig. 7. The straps were fillet welded to the webs of the I30 beams. The web of the I30 beams was fillet welded to the web of the I60 beam. A seat was welded from the compression strap of the I30 beam to the compression flange of the I60. Welding was done in field position. First the web fillets were made. The butts then were half filled with four layers of $^5/_{32}$ in. 6020 electrode. The straps were fillet welded to the webs, after which the butts were completed with 11 layers of the $^5/_{32}$-in. electrode. The roots of the butts were chiseled out and finished in three layers overhead with $^1/_8$-in. 6020 electrodes. Finally the seats were welded. Fracture occurred at or close to the junction of the tension flange with the butt weld to the strap. The opening in the web acted as a notch in the tension zone of the beam. If the edges of the flame-cut opening had been machined

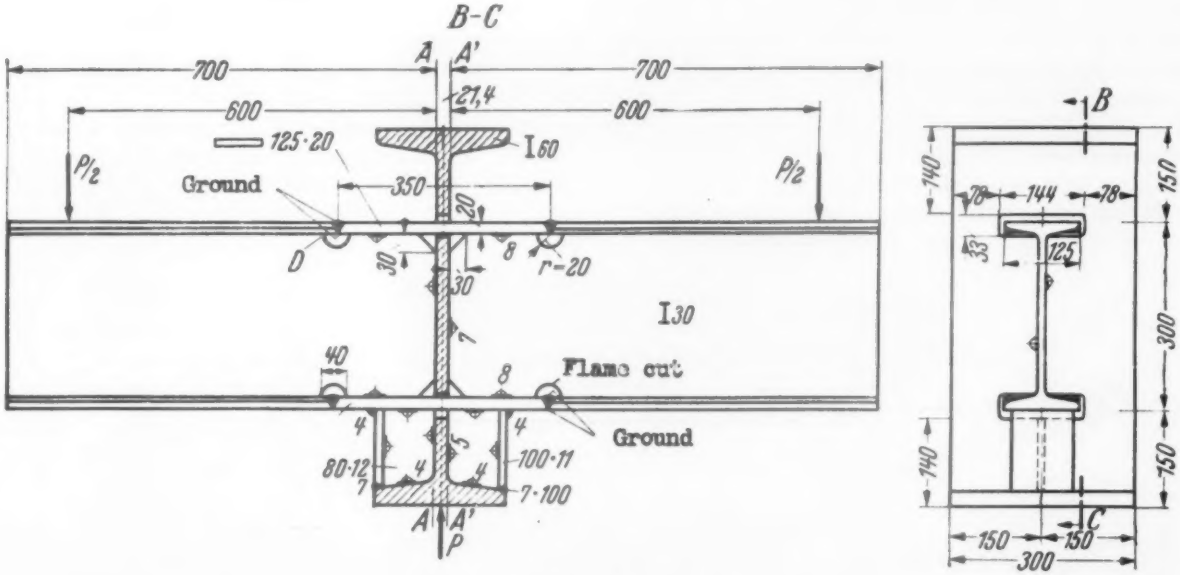


Figure 7

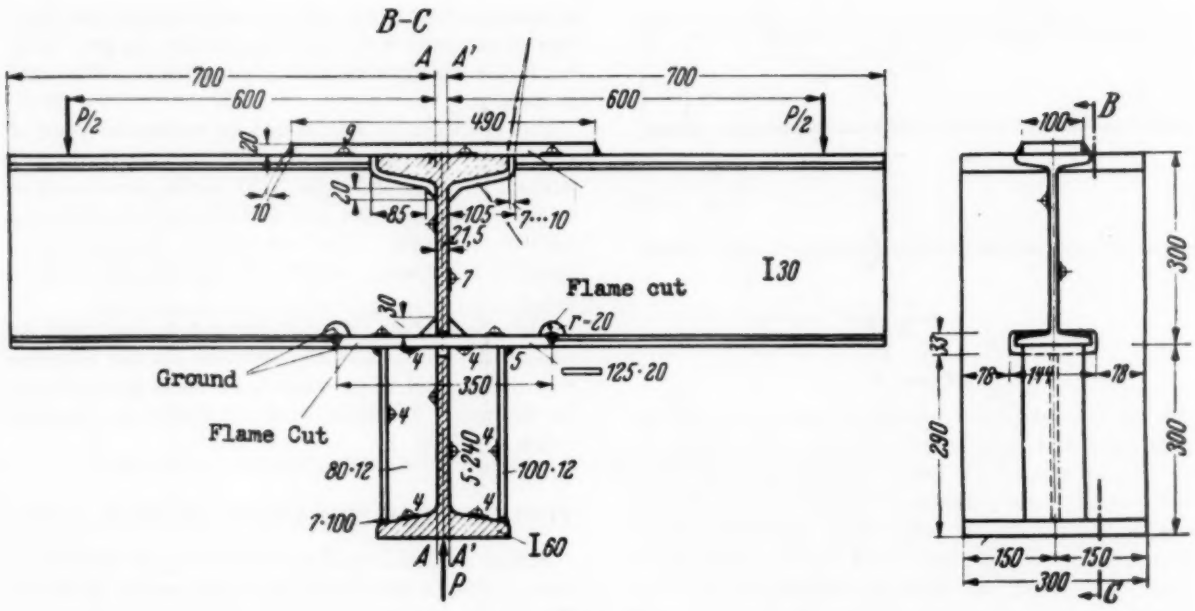


Figure 8

the endurance limit might have been higher. As it was, the endurance limit was only 12,800 psi.

In the specimen of Fig. 8 a strap spanned the tension flange of the I60 beam. Otherwise the specimen was welded in the same way as Fig. 7. Fracture occurred at the end of the fillet connecting the tension strap with the tension flange of the I30 beam. There was a sharp stress concentration there. The endurance limit was 11,300 psi.

In the specimen of Fig. 9 an I30 beam was substituted for the through I60. Straps connected the flanges. The welds were made in field position. The webs were welded to the through beam, after which the fillets were made in the tension and compression zones. Fracture occurred at the junction of the fillet at the end of the tension strap with the tension flange of the beam. The endurance limit computed on the cross section at this point was 15,600 psi. However, this point is at a considerable distance from the sections A-A and A′-A′. The endurance limit at these sections computed on the strap cross sections is again 15,600 psi, but computed in the beam cross section the endurance limit is 27,000 psi.

In terms of load, the endurance limit of the specimens

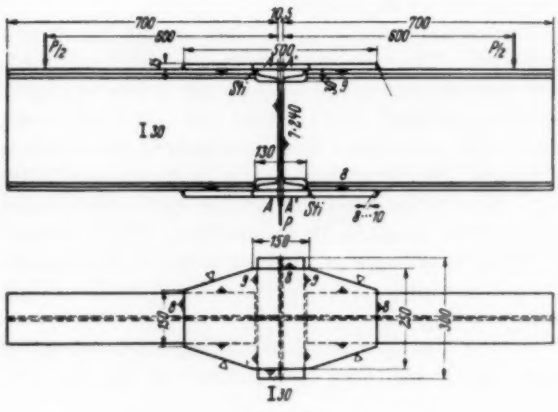
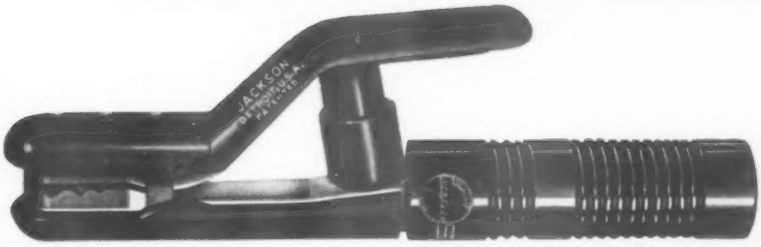


Fig. 9

is: Fig. 3, 64,000 lb; Fig. 7, 66,000 lb; Fig. 8, 53,000 lb; Fig. 9, 90,000 lb.

The basic Bessemer steel in the beams contained 0.06 C, 0.41 Mn, 0.061 P and 0.033 S. The yield strength was 43,000 psi, the tensile strength was 62,000 psi.



MODEL
A-W
for electrodes
1/16 thru 1/4"
14
OUNCES

MODEL
A-5S
for electrodes
1/16 thru 5/16"
21
OUNCES

For Greatly Reduced Operator Fatigue

JACKSON *Featherlight* HOLDERS

give the most cool-working capacity per ounce of weight

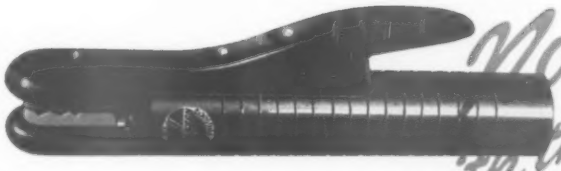
Choose from these JACKSONS when a truly lightweight holder is desired. They are the only electrode holders using a lightweight metal in the tongs. All have replaceable jaws of high-copper alloy. Many users prefer them for work of all kinds, and, within their rated capacity, may be counted on for long, economical service.

MODEL
JH-3
for electrodes
1/16 thru 1/4"
15¾
OUNCES

MODEL
JH-2
for electrodes
1/16 thru 5/32"
9½
OUNCES

Sold World Wide . . . through Distributors and Dealers

STREAMLINED



Now with the new Fiber Glass insulation

FEATHERLIGHT HOLDERS MADE ONLY BY

JACKSON
PRODUCTS
WARREN · MICHIGAN

NEW!

SPOT WELD without jigs or back-up plates

Now you can spot weld with complete maneuverability — and as fast as you can pull the trigger — with the new portable AIRCOSPOT® Gun.

With **AIRCOSPOT,** Air Reduction's new inert-gas-shielded spot welding unit, you simply touch the water-cooled gun to one side of the work and pull the trigger. In about a second you have a spot weld. It will be a good one, too, because **AIRCOSPOT'S** inert gas shield completely protects the hot metal from contamination by the air.

Write today for prices and folder that provides detailed information.

AIRCOSPOT welds all sheet steels — including stainless up to 3/32" — to bottom sections of varying thickness.

AIRCOSPOT is fast. Once the controls are set, you can make thirty or more welds a minute.

AIRCOSPOT is easy to use. Operators need no special training. The welding cycle is fully automatic.

AIRCOSPOT is handy. Gun weighs four pounds, is nine inches long. All connections—current, gas and water—are through a single control panel.

AIRCOSPOT is rugged. No abuse-sensitive high frequency or electronic circuits, because Gun is of electromechanical design.

at the frontiers of progress you'll find

AN AIR REDUCTION PRODUCT

AIRCO®

OFFICES AND DEALERS IN MOST PRINCIPAL CITIES

AIR REDUCTION

60 East 42nd Street • New York 17, N. Y.

Air Reduction Sales Co. • Air Reduction Magnolia Co. • Air Reduction Pacific Co.
Represented Internationally by Airco Company International

Divisions of Air Reduction Company, Incorporated